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The
PHOTOGRAPHIC
NEGATIVE

by
HERBERT C. MCKAY, F. R. P. S.

IN FOUR VOLUMES
VOLUME 2

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Table of Contents

IV Developing the Negative..... 209

"Correct" Exposure and Development; Density and Contrast; Definition, Detail, and Texture; The Routine of Developing; Loading the Tank; Filling and Emptying Tanks; Elementary Developing; Step-by-Step Development; Developer Formulas; Carbonate Conversion; Percentage of Accuracy; Use of Various Alkalis; Laboratory Routine; Checking Results; Time and Temperature.

V Special Methods in Development..... 277

Controlled Development; More About Graininess; Finegrain Developers; Restrained Development; Ultra-Miniature Development; Physical Development; Three-Color Separation Negatives; Development at High Temperatures; Printing from Wet Negatives; Other Uses for Glycerin; The Reversal Process; Solarization; Limited Water Supply; Dye Toning.

VI Hardening, Fixing, Washing, and Drying 355

Stop Bath; Hardening; Fixing; Remedy for Fading; Hypo and Other Agents; Addition of Acid; Use of Hypo in Photographic Processing; Acid Salts; The Hardener; Capacity of Fixing Solutions; Formulas; Washing; Tank Washing; Drying; Two Systems of Controlled Drying; Importance of Proper Drying; Cleaning and Polishing; Storing.

IV

DEVELOPING THE NEGATIVE

IV.

Developing the Negative

BEFORE the photographic negative can be developed it must be exposed to the action of light—a subject which was discussed generally in a preceding chapter. However, because photography is more of an art than a science, the exact method and degree of exposure will depend upon the general pictorial effect desired. This, in turn, will influence the character and degree of development.

“Correct” Exposure and Development.

We have already examined the nine specific types of negatives which may be obtained through departure from normal exposure, normal development, or both (see Chapter II, Fig. 20). So far as the laboratory technician is concerned, the only negative which is worth considering is the one which has received both normal exposure and normal development. Other series of nine negatives similar to these have been pub-

lished repeatedly throughout the past three or four decades, and more often than not the center negative, **NE-ND**, has been indicated as the one which has received correct exposure and development. So far as the technician is concerned no objection can be raised to the use of the word "correct," but the pictorialist and the amateur photographer in general have plenty of cause for objection.

It must never be forgotten that in photography there is no fixed condition which can be designated as the correct one. The conditions and manipulations **which yield the desired result**, and which are variable, are necessarily the correct ones. In other words, "normal" is not necessarily "correct" in every case.

The set of nine negatives was presented to illustrate the specific results obtained by an increase or decrease in exposure, development, or both. The beginner in photography may well use the set as an index of the errors which he has unquestionably committed. But as he progresses he will find the negative series of even greater value in indicating the direction in which he must depart from normal procedure in order to obtain a result that will produce the picture which has been conceived and is in process of being brought into concrete existence.

Without going into the ramifications of the various schools of pictorialism, and without entering the discussion of few or many tones in a picture, the influence of external conditions can be shown by one or two examples. For our first subject let us consider the texture pattern as seen in certain types of weathered building stone. We will assume that you have made pictures of some old building, including detailed shots of courtyards, staircases, and so on, and that you have noticed the interesting pattern in the stone itself.

The detail of the pattern has not been etched deeply, and ordinarily the light will not strike the stone from

the steep angle which is necessary to emphasize texture. Photographic means, then, must be used to make the detail visible. It will be recalled that the ordinary negative may have a range of tones as great as 100 to 1, or even more. Because the ordinary subject exhausts this complete tonal range, the indicated exposure is based upon a compromise which will permit recording the extremes of shadow and highlight detail. In the subject which we are considering there is no deep shadow. Incidentally, there is rarely any brilliant highlight, but this does not enter into the problem which is being discussed. In this case the exposure given is the **least** which will serve to record the darkest part of the subject. This exposure is considerably less than it would be with the ordinary subject containing heavy shadows. The net result, then, is that the exposure given would ordinarily be considered a decided underexposure.

The amount of exposure received by a sensitive film will determine the over-all density of the finished negative. In the case of underexposure, normal development will produce a negative somewhat lacking in density. When the average subject has been underexposed, it merely means that the shadows have been lost while the highlights are fully exposed and in some cases actually overexposed. In a subject of that kind, overdevelopment would result in blocked highlights, and the negative would be extremely poor. However, in the subject we are considering there are no extreme highlights. Thus, in view of the fact that there is no danger of increasing density, we may take full advantage of the characteristics of overdevelopment. The negative is given at least double the normal development, with the result that the contrast is greater than in the original subject; the texture or design which we wanted to photograph is made even more visible. Through a combination of underexposure and

overdevelopment we have obtained a photograph which is definitely better, both technically and in a point of interest, than it would have been had the negative received normal treatment throughout.

Again there are certain occasions when we want to eliminate undesirable elements in the picture by obscuring them in deep shadow. If the scene happens to include a figure, and if the lighting is somewhat flat, an exposure which is slightly under or even normal, followed by a fifteen to twenty per cent increase in developing time, will often give a more brilliant result.

Then, of course, there is the well-known case of extending the tonal range of a photograph through gross overexposure followed by extremely superficial development. It is often said that this method of processing usually results in a negative showing streaks or other results of uneven development. I have often used the method, and have not experienced any difficulty even when development was cut down to one-fifth normal time. The classic example of this particular method is the photograph of an interior, say a living room, in which the individual boards in the floor can be distinguished in the deep shadow under large pieces of furniture; in the same print details in flowering plants in the open garden are perfectly distinct as seen through windows in the room. In this case the rule is followed. The exposure given is that for the shadow detail in the room itself. Development of the negative in such a case makes use of a diluted developer, and should be done by visual inspection following the use of a desensitizer. Trying to develop such an exposure by time and temperature control is a pure gamble. However, that is beside the point. The important thing to keep in mind at all times is the fact that the correct development for any negative is that departure from normal procedure which will most nearly produce the desired effect.

One successful pictorialist made a remark several years ago which presents the case briefly and truthfully: "A successful photographer is one who can deliberately make mistakes of known degree and direction of departure from the normal."

Strictly speaking, from the point of view of the research worker who will admit only one standard of normal, these deviations from the normal are all errors. This may be one reason why so many beautiful photographs are made by those who have absolutely no technical knowledge of processing, and who are not inhibited by a technical conscience.

It has often been remarked that development is affected by the preceding exposure, but this is only a half-truth. Exposure and development are specific steps in the production of a negative. They are closely interrelated, and a knowledge of this relation is utilized in controlling the combinations which give the best result. However, this interrelation should never be made a basis for trying to compensate errors of exposure by manipulation of development.

Density and Contrast.

Among the specific types of negative we find two characteristics which are often confused and which are definitely different. These characteristics are **density** and **contrast**. Density, as a negative characteristic rather than as a specific measurement of a restricted area, is the heaviness or blackness of the negative itself. A negative may be very thin and delicate, in fact so thin that the image cannot easily be seen until the film is laid directly upon a sheet of white paper. Such a negative has very little density. However, this same negative may have a low, a normal, or a high range of contrast.

It will also be understood that a negative may be

of average or normal density, or it may be heavy and black. Of course, there are extremes which cannot be passed without imposing limits upon contrast. But there is a considerable range of over-all density from the thin negative to the heavy one which may, and very often does, include negatives with a full range of printable contrast.

The contrast of the negative has been considered briefly, and will be discussed more thoroughly in a later chapter dealing with sensitometry. At this point we need only recall that if the highlight areas are one hundred times darker than the shadow areas, the negative is a contrasty one; if the difference is only ten or fifteen times, the negative is one of low contrast. A good average negative is one in which the range of contrast may be anywhere from 40 to 1 up to 80 to 1.

Definition, Detail, and Texture.

The negative should have a moderate to fine grain structure. It should be sharp, and it should retain a microscopic range of contrast which is responsible for the reproduction of texture. There has been a considerable amount of discussion concerning the terminology of negative characteristics. It has been stated that **definition** is a separation of one tone from another by a sharp edge, while **detail** is definition which retains **texture**. This distinction is true to a certain degree, but it is misleading. For example, a 16x20 enlargement may be made from a 35 mm negative. There may be no obvious diffusion present, yet the picture may be entirely lacking in definition. The extent or the degree of perfection of definition is expressed numerically in the resolving power of the negative. It is impossible to have good definition unless the actual weave of the cloth in clothing can be seen, unless the individual hairs on the head and eyelashes can be seen,

unless the minute cracks of a shingled roof can be seen. Such definition is not always desirable—in most pictures it is definitely undesirable. But we are not discussing esthetics; we are discussing the cold technical aspect of definition.

Detail has very little relation to definition. In fact, detail is opposed to contrast. If you have a negative of high contrast, several grades or degrees of highlight are merged into pure white in the print, while several tonal gradations in the shadow all merge into a solid black. To a certain extent the same thing is true of the middle or half-tones. On the contrary, there is no highlight or shadow loss in a print which is inclined to be flat, and every minute differentiation in the object can be seen distinctly.

It has been said that detail is that exact reproduction which preserves texture. This statement is also open to question. Texture is that quality of a picture which enables us to sense the effect which the surface depicted would have upon our sense of touch. Reproduction of texture depends upon a skillful blending of definition and detail. Extreme definition produces a harsh result. Extreme detail is found in a flat, grayish, and rather unattractive print. Contrast gives us a soot-and-whitewash effect, which is perhaps the worst of the three.

If, in making a negative, the object is carefully lighted to make its characteristics clearly visible, it can be photographed in such a way that the texture is retained. Because texture is a quality ordinarily imparted to the original by extremely minute units of structure, sufficient definition must be included in the negative to produce each of these minute units and keep it separate from its fellows. Texture is a result of the play of tones upon exceedingly minute units of structure. Very often the range is extreme, from brilliant highlight to black shadow. These conditions

are not observed visually or in the finished photograph because the area of extreme tone is almost microscopic. However, the visual appearance is a guide to lighting for texture, and this is followed by an exposure balanced for extremes of light intensity. When we add to the definition of the unit a lighting and an exposure which will retain the contrast range and the modeling of each individual unit of structure, we have successfully recorded the texture of the original.

Too little development may easily cause brilliant textures to appear dead, whereas too much development will often give a brittle, hard appearance to an originally soft texture. A common example is overexposure and overdevelopment when making photographs of flowers, a procedure which results in a total loss of the delicate texture of the petals. In the final print they appear to have been cut out of cardboard or thin metal. Therefore, careful development set to a standard which will best complete the texture reproduction is an essential step in making a picture.

Assuming the use of an emulsion with normal resolving power, and of equipment which will hold the sensitive surface correctly in the focal plane, definition is a matter of the camera and its lens. That this definition may later be degraded in enlarging by reason of an enlarging lens of uncertain quality in no way affects the original definition in the negative. Texture as well as contrast, and to a lesser degree detail, are strongly affected by lighting. Detail and contrast are not deeply affected by lens performance within the accepted limits of modern lens standards, but texture requires excellent lens quality.

Definition is affected very little by any step in development. Texture may be saved or ruined by development. Contrast and detail are essentially products of development, modified by a preliminary exposure designed to produce these results.



This subject called for normal exposure and underdevelopment to emphasize texture in the suds, shown by graded range of tones.

Again we come to the unavoidable conclusion that the characteristics of the finished negative are a result of an intimate complexity of the several individual factors of both exposure and development.

The Routine of Developing.

I have repeatedly been warned against the crime of going into "offensive" detail. No one who is sincere will object to reading or listening to those things which he already knows, providing they are accurate. The only true danger is that of omitting something. There is a very good reason for such detail, as a true anecdote will show.

Recently a young man, in recounting the position of the beginner, told me about his own case. It seems that he had owned a modest camera for a year or so, and had his processing done at the corner drugstore. For Christmas he received a small darkroom outfit, and, of course, he had to try it out right away.

The entire family accompanied him into the darkened kitchen where he attempted his first negative development. As he said, the negatives received from the drugstore were always black, so he unrolled the film, threw away the strip of white "paper" which he found inside, and spent a full hour see-sawing the black paper through the developer—but with no result! He would have been at a total loss had not his sister insisted that he try the white "paper." Of course, even though it was ortho, the hour's exposure to the safelight had fogged the film, but at least he learned that it was the white strip within the roll which was to be developed, not the black paper. His story was checked, and in no instructions except one publication could we find any statement as to which part of the roll was the sensitive material.

But, you will say, anyone with ordinary intelligence

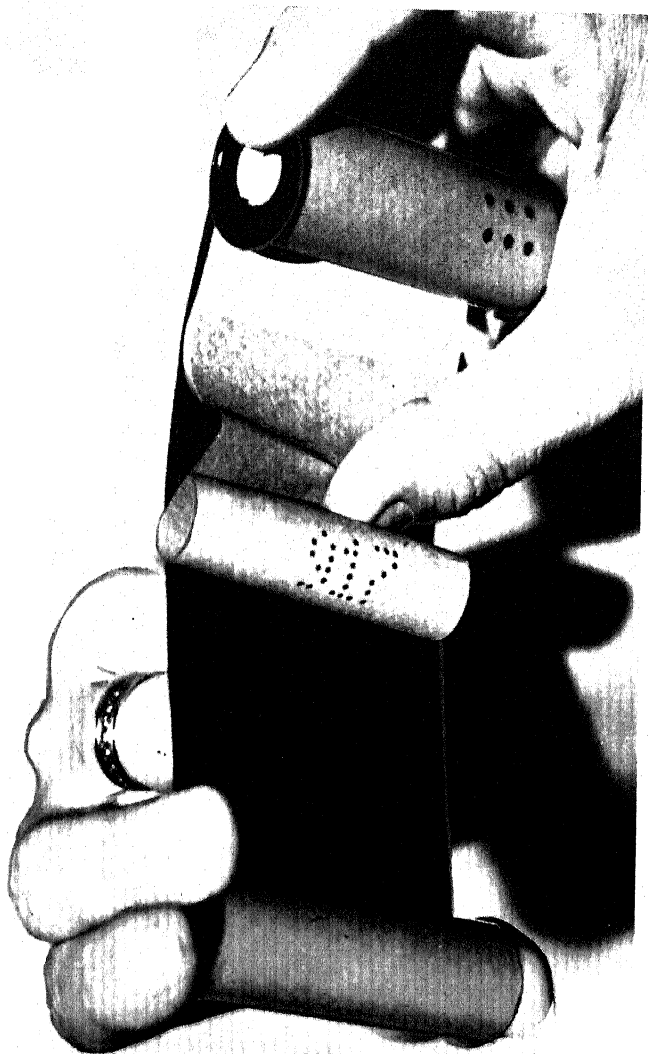


Fig. 36. Loose gummed paper tab is torn off end of film strip before loading it into reel-type tank.

would know that! This doesn't follow at all.' Photography is a specialized activity, and there is no reason why anyone should have an instinctive knowledge of its workings. Therefore I shall try to be explicit.

There are three principal types of film packing, the roll, the pack, and the sheet film, all of which have been briefly described. The last is the simplest, as it is merely a sheet of film cut to size for use in individual holders or magazines. Inasmuch as the film must be removed from the package and placed in the holder, there will be no difficulty in removing it for processing.

The roll is the most common form of film package. It consists of a long ribbon of paper, black on one side and colored on the other. As a rule, red paper indicates orthochromatic, green paper indicates panchromatic film, while yellow is used on direct-color film; but sometimes this rule is not observed. The paper is merely a protective device permitting the film to be loaded in daylight. It also bears markings and numbers which permit accurate spacing of the exposures upon the film ribbon.

Inside the paper, and about half its length, is the actual sensitized film. It is a creamy white, with or without a colored backing which may be blue, gray, green, red, or some other color. This color disappears in the processing. The film strip is attached to the paper strip at the leading end only. You will remember that Eastman films have a gummed paper tab attached to the trailing end. This tab must be attached to the paper before developing in the old-type Eastman apron tank. The paper is carefully unrolled in subdued light until the tab is barely visible. It is moistened, and the paper re-rolled. When using the ordinary reel type of tank with a spiral film support, the tab is torn off and discarded (see Fig. 36).

The actual loading of rollfilm is preceded by unrolling the paper until the end of the film is reached.



Fig. 37. Unloading film pack. Light-tight cap is removed from end of pack, and films withdrawn from holder. Agfa Ansco

Experienced workers simply unroll the entire length, remove the film, discard the paper, and then proceed to load the tank reel. It is advisable for beginners to unroll only to the end of the actual film strip and leave the rest rolled in the paper until the film end is attached to the reel or has been started into the groove of a free-film type of reel. The film is then loaded, unrolling the paper as the reel is loaded. This protects the film from finger marks.

The filmpack consists of a dozen sheets of film, each attached to a separate piece of black paper. A protective cap at the end of the pack is removed by pulling it upward from the pack, which is held upright. The open pack will then permit the removal of the exposed, paper-backed films, as shown in Fig. 37. Before actual loading, the films are separated from their paper backs simply by tearing the paper away at the attached edge. It is advisable to tear each sheet loose as it is loaded into a holder or cage, instead of freeing all the films first and then loading.

Loading the Tank.

Rollfilm tanks are usually of three types. The oldest tank now in common use is the Eastman daylight loading tank. In this tank both the film and paper are rolled into a celluloid apron which has rubber strips sewed along its edges to keep the layers separated.

The apron is rolled on a temporary shaft and supported within a wooden case. The developing reel is supported on another shaft, and both shafts have handles extending outside the case. The film is placed in a support inside the tank. The end of the apron is attached to the developing reel, and the end of the protective paper of the film roll is run beneath a rod and bent over. The case is now closed and the reel rotated by means of its crank handle. This winds the

apron upon the reel, and at the same time winds the film in between the layers of the apron. The spool is then removed from the tank in subdued light, and placed within the developing tank, which is then closed. After development, the developer is poured off, the tank and contents rinsed with water, and the hypo poured on.

More recent tanks are either the apron type or the spiral type. The spiral type is also subdivided into the fixed-film and the free-film types. The apron tank is similar to the Eastman except smaller. The apron is clear celluloid and only long enough to accommodate the film itself; the layers are kept separate by a row of "dimples" pressed along the edges of the apron. This apron is wound upon a skeleton type of supporting reel. Obviously this tank must be loaded in the darkroom. (It is to be remembered that any darkroom loading may also be done in the changing bag.)

The apron is attached to the spindle of the reel, the end of the film placed against the apron, and the two rolled together. When the apron is rolled up with the film inside it, the whole is placed in the tank. The tank is then closed and removed to daylight for subsequent steps of the process.

Since the apron does not always allow free circulation of the developer, and as it must be carefully washed and dried after use, this is an awkward process. Moreover, the apron tank is usually more costly than the spiral type, and for these reasons is now rarely used.

The spiral reel tank has a reel whose upper and lower plates contain spiral grooves which hold the edges of the film, and so make the film provide its own support. The spiral form of the winding keeps the film sufficiently rigid even when it is wet. As there is nothing but film between the upper and lower plates (except at the center) there is free circulation of developer, and the reel is easily kept clean.

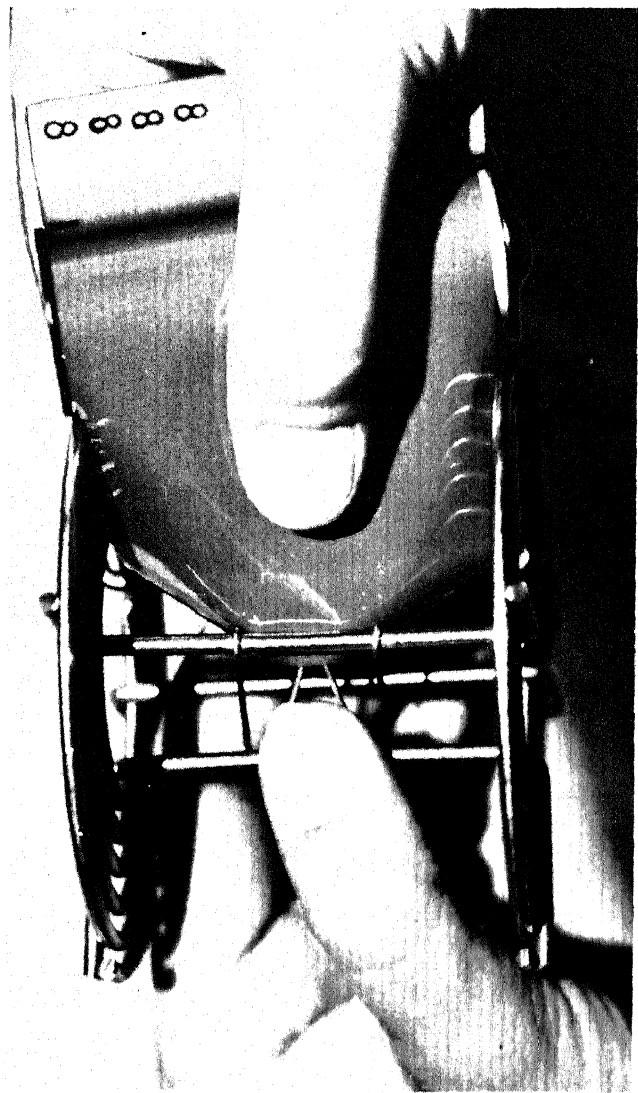


Fig. 38. End of rollfilm is attached securely to spring clip before it is loaded into Nikor wire film reel.

Of the fixed-film type, the Nikor stainless steel tank is a typical example. The "grooves" are formed by soldering a spiral of steel rod to a spider support. Thus the cage is made of steel wires, smooth, open, and easily cleaned. At the center a spring bears against one of the four central supporting rods. The end of the film is placed beneath this spring to hold it firmly in position (see Fig. 38). The film is unrolled and inserted between the two spiral wire plates. This requires that the film be bent somewhat. The end of the film must be placed so that the film is exactly midway between the inside surfaces of the end plates. Most trouble in loading this type of reel lies in trying to start with the film too far off center.

These tanks have a curved steel guide plate accessory which is used to aid in loading. Many photographers, however, discard this device after loading a roll or two, and guide the film into the cage by the fingers alone. The film is attached to the center so that when it is wound into the reel the emulsion will be **inside**. That is, the film follows its natural curvature. If, when loading the reel, the film tries to twist to one side or the other, it indicates that the edge has jumped a groove. Unwind the film about one turn and rewind. The film is fed into the reel with the thumb and finger of the right hand on opposite edges compressing the film into a slight curve. As soon as the film strikes the curve of the roll in the reel this cross curve will straighten out, because it is difficult to bend film in two curves simultaneously. The reel is turned slowly with the left hand, and with a little practice it can be loaded in about thirty seconds (see Fig. 39). Practice loading your tank with an old piece of film in full daylight. As the reels generally must be loaded in total darkness, such practice is invaluable.

There are several good free-film tanks on the market. Most of them are made of bakelite or a combi-

nation of some plastic and metal. The free-film reel has no provision for attaching the end of the film before loading. The grooved channels are highly polished to facilitate loading, and the end of the film is started into the open end of the outside groove. Usually moulded lugs indicate the position of the groove and prevent the film from jumping the track at the start. The film is pushed into the groove so that it spirals around and around until the full length is in the reel. Then the end is tucked into the short slots provided; they hold the film in the reel so that it will not unroll in the tank during development (see Fig. 40).

When 35 mm film is loaded into such a reel, it should have the leading end cut even and the corners rounded to prevent its gouging into the groove and sticking. The trailing gummed tab on Eastman films often produces a hard, curved "bump" in the film at the end, which tends to stick in the grooves. This should be cut off carefully, and in any case clipping the corners will aid in loading.

When about half or two-thirds of the film is in place, it often sticks. When this happens, pull back on the film about an inch and try again. If this doesn't help, curve the film to give it rigidity by squeezing between thumb and fingers, and with a quick thrust try to overcome the obstacle. If this fails, make sure the hands are free from perspiration or dampness, grasp the rolled film between the end plates of the reel, and turn the whole outer layer. If this fails to free the film, withdraw it and examine the end by feeling to make sure it is smooth. A rough film end will usually cause trouble, but if there is a single drop of moisture in the groove of either plate it will "glue" the film to the reel and make it almost impossible to advance the film any farther. Always make sure the spiral plates are absolutely dry.

Loading the free-film reel should also be practiced

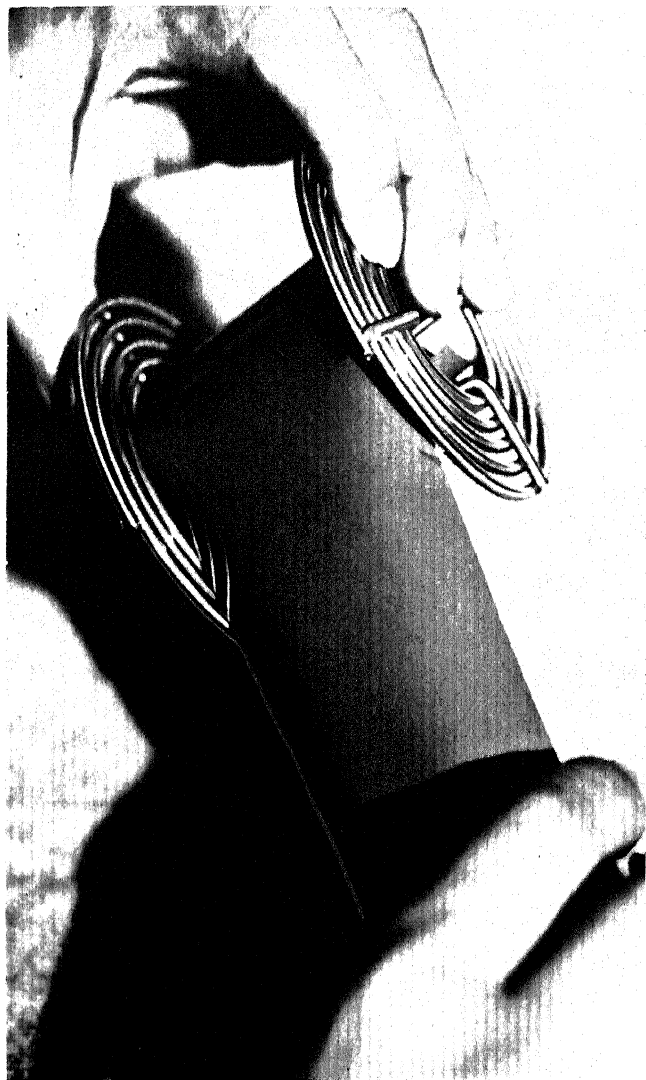
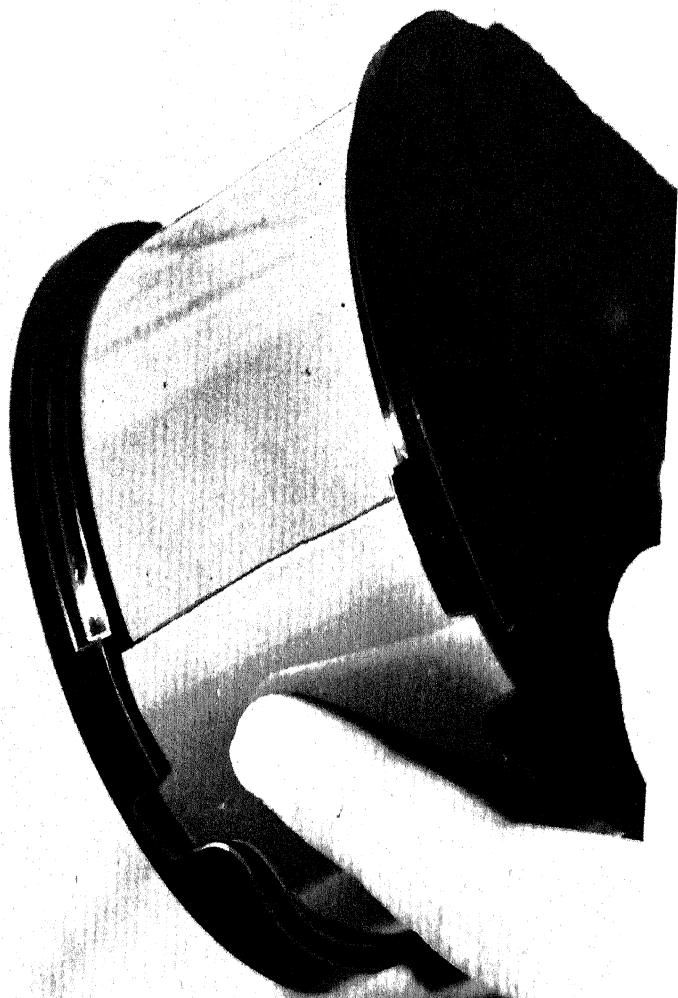
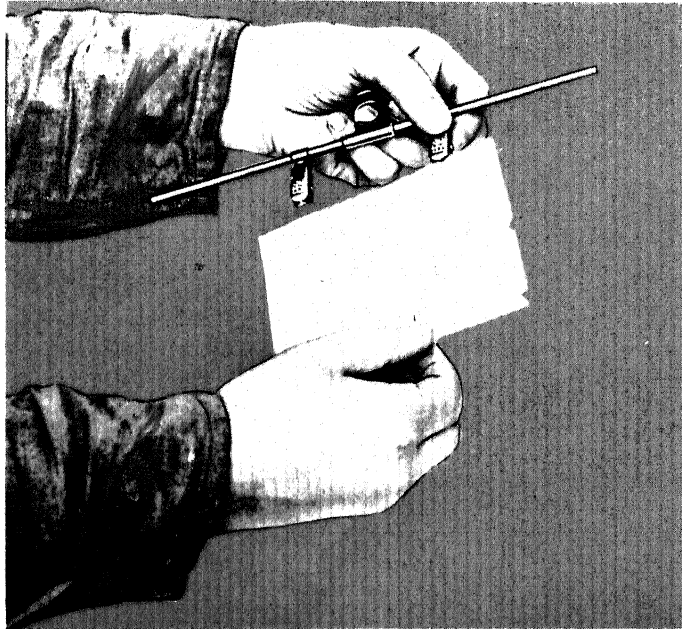


Fig. 39. Film strip is kept slightly bent between thumb and fingers as it is fed into fixed-film type wire reel.



in daylight. Both reels are extremely simple to use, and there are many amateurs who are ardent champions of one or the other type. The fixed-film reel usually has a smaller tank which requires less space and less developer, and it can be used damp (although this is never advised), but I use the two types of reel and find both of them entirely satisfactory. When the reel is loaded it is placed in the tank; the tank is then covered and taken into daylight for the actual developing operation. Modern tanks are provided with trapped openings which make it easy to fill and empty



Eastman Kodak Co.

Fig. 41. Individual sheet and pack films can be clipped to a metal rod hanger for darkroom development in an open tank.

them with no danger of light reaching the film during the process.

Pack and sheet films will be considered together, as in most cases they are developed in similar tanks. The open tank is simply a box made of plastic, stainless steel, monel, hard rubber, or the like, which contains the developing solution. The films (after removing the paper backing in the case of pack films) are placed in a sheet film hanger (see Fig. 29, Chapter III) or attached to a rod hanger by means of small spring clips (see Fig. 41). The film is lowered into the developer, with the ends of the hanger resting upon the edges of the tank. Of course, the open tank is suitable only for darkroom developing. Modern tanks have been designed so well that there is really little reason for using the open tank.

One of the earliest closed tanks was an adaptation of the glass plate tank. Of these the Dallan was one of the first to enjoy wide popularity. It made use of a principle which is still widely used, namely, that a film bent in one direction will not bend in the others. Curved film holders were made to fit the usual plate tank. The films were first inserted into the holders, which were slightly curved, then these holders were placed in the plate cage, each being held in place by edge grooves. There are no particular instructions for loading such tanks as the films go into the sheaths easily, and these in turn fit snugly into the supporting grooves. The films are placed in the sheaths with the emulsion facing away from the metal frame of the sheath. One can obtain hard-rubber tanks fitted with a removable metal rack grooved to hold plates or films. These tanks have light-tight covers with openings to permit filling and emptying in daylight.

At the present time there are three types of film tanks in general use for developing sheet and pack films.

The intermediate tank is rectangular, quite large in comparison with the film size accommodated. The films are pushed into curved slots in the rack and thus held apart from one another. The rack is placed in the tank, the tank covered, and development carried on in day-

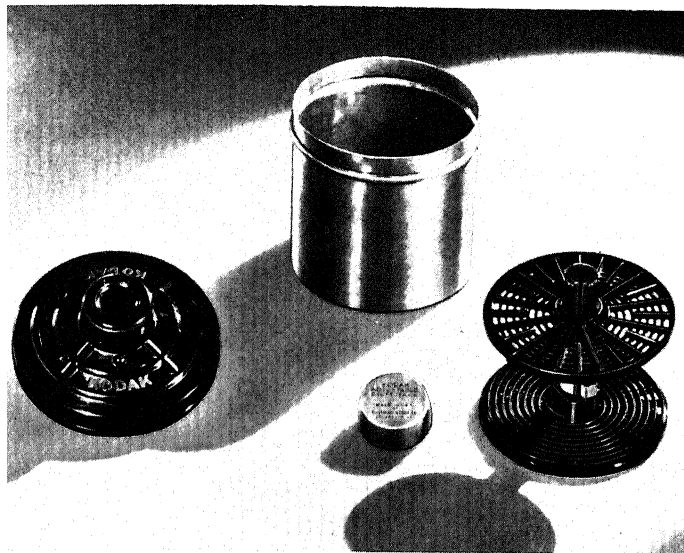


Fig. 42. Kodak rollfilm tank and adjustable reel. An accessory unit which accommodates sheet and cut film is available.

Eastman Kodak Co.

light. The rollfilm tank adapted to sheet or pack film employs a separate rack, the sides of which are cut away so that the films can be introduced one at a time and held securely for development (Fig. 42).

The spiral cage for pack and sheet film is a direct adaptation of the rollfilm reel, and has proven one of the most successful of all single-film tanks. A series of spiral slots is cut in the end plates of the cage. The

top plate slides up and down on rods, and thus the cage is adjustable for various film sizes. The film is introduced at the edge of the cage and pushed inward; it follows the spiral curve toward the center, and because of its curvature is held rigid (see Fig. 43). The tank for a dozen films up to 4x5 inches in size is extremely small, being only about twice the size of a tank adapted to $2\frac{1}{4} \times 3\frac{1}{4}$ size rollfilms. It is all steel, and has the cleanliness and compactness which characterize all the tanks of this construction.

There are no particular instructions for loading the sheet film tanks, aside from the suggestion to practice in daylight with old film. It will be found that jamming of the film results from trying to insert it with the emulsion on the outer curve, or by starting the film into the slot at an angle. If these errors are avoided, the film slips into the cage with no difficulty.

Filling and Emptying Tanks.

All daylight tanks have some provision for filling and emptying without exposing the contents to light. In the early Eastman tank the loaded reel itself is light-tight, and the tank is simply opened to change solutions. In modern tanks the means for filling usually consists of some kind of light-tight channel in the lid. In the plastic rollfilm tanks, the center of the reel often forms part of the light trap, while in the steel tanks the trap is contained within the lid itself. Among the sheet film tanks some are arranged like the rollfilm type, some have the drain at the bottom of the tank, and some have it in one corner of the lid. Such variations in design have little effect upon the efficiency of the tank.

The steel tanks require about fifteen seconds for filling or emptying, while the plastic tanks usually require about twice that time. They drain through an

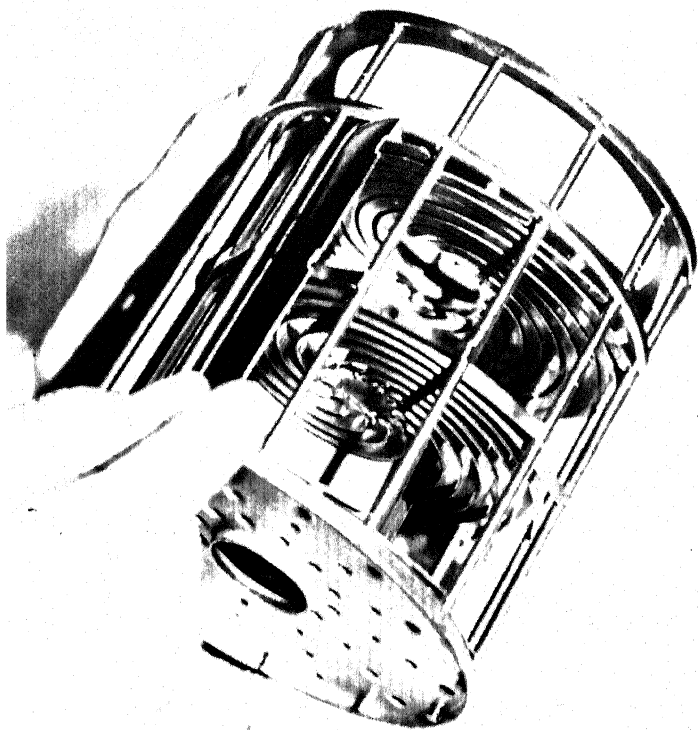


Fig. 43. In loading the Nikor spiral cage, the individual pack or sheet films are introduced at the edge and pushed inward.

opening near the edge of the cover, and have restricted ingress for solution which must pass down through the center of the reel and upward after diffusing along the tank bottom. Speed of filling is important because of the uniformity of development which follows a rapid filling. Once developer is poured into the tank, a continuous stream should be maintained. If even a short period is allowed to elapse between two periods of pouring, the negative will show a line of demarcation.

Many square tanks for cut films have an inadequate funnel moulded into the lid. Such tanks can be filled more rapidly by cutting an aluminum funnel stem to fit the opening tightly and then using the funnel to fill the tank. Care must be taken that the funnel does not go clear down to the light trap plate, or the solution cannot flow from the funnel into the tank.

Plastic tanks may be checked by looking at the height of the solution in the central core, or by filling until the solution just reaches the top of the inner opening. Steel tanks are best filled by holding them at about a forty-five-degree angle and then filling until the solution is just visible in the bottom of the filling aperture. This will provide sufficient solution to cover the reel without having the tank so full that it will leak between the tank and the cover. With any tank, filling may be done directly from the stock bottle, but it is advisable to empty the tank into a large graduate or measuring jug and to refill the bottle from this if the developer is not to be discarded after use.

Elementary Developing.

It is advisable for every amateur to develop a few rolls of orthochromatic film, using a safelight to make the process visible. This familiarity with the actual process of development will make it easier to under-

stand what is taking place during the routine tank development in total darkness. A safelight, three trays, and mixing vessel are required. The developer is placed in one tray, water in the next, and hypo in the last. These are placed so as to be illuminated by the safelight; naturally this is a darkroom process.

When the trays are filled, turn out all lights except the safelight. Break the seal of the roll. Unwind the roll until the end of the film is visible. Attach a film clip or spring clothespin to this film end and unroll the balance of the film. Attach a clip to that end also. Holding one clip in each hand, lower one end of the film into the developer and then raise it, lowering the other hand at the same time so that a loop of the film rides through the developer. Reverse the motion and continue to "see-saw" the film for the required time, watching the image grow as the time passes.

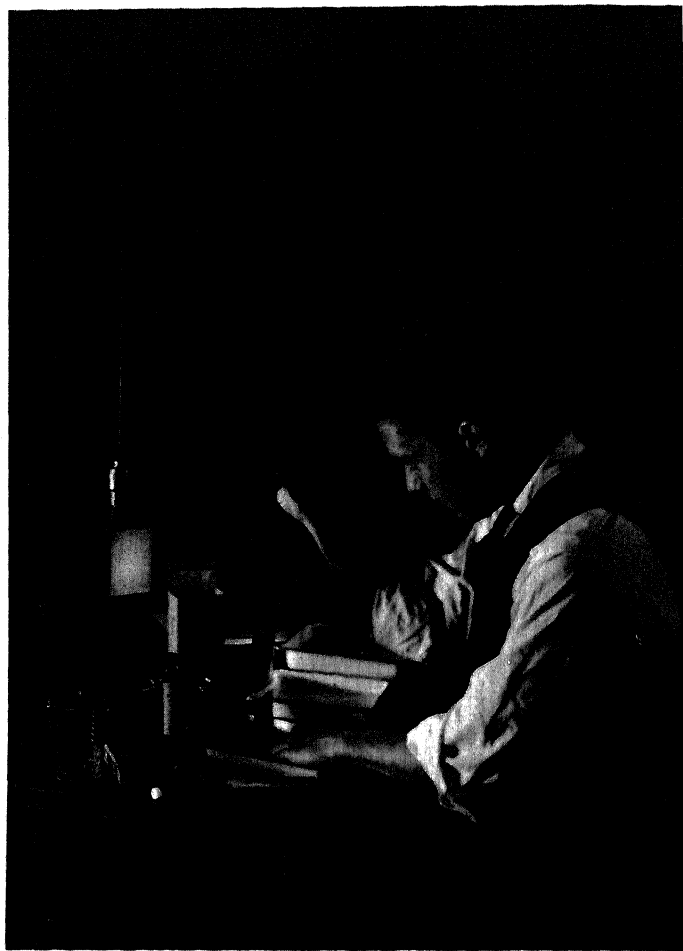
When development is complete, pass the film once or twice through the water; repeat the see-sawing in the hypo until all milkiness disappears and the film looks the same from both sides. Turn on the white light and continue fixing for two or three minutes.

Rinse the film thoroughly in three or four changes of water, wash in a tray of running water about twenty minutes, wipe down as explained later, and hang it up to dry. Several of these steps in elementary developing are illustrated in Figs. 44, 47, 48, 49, and 50 on the following pages.

Step-By-Step Development.

The exposed film is conveniently at hand. The developer and hypo are mixed ready for use. A clean, dry tank and reel are ready for use. These points have been discussed in detail.

1. Take film and tank into the darkroom, and be



Eastman Kodak Co.

Fig. 44. Every amateur should develop a few rolls of orthochromatic film in a tray, by a safelight, and watch what takes place.

sure that there are no light leaks in the room. (Alternate: Place tank and film in a changing bag and button the flap securely.)

2. Break the seal on the roll. (Open the end of pack; remove slide from filmholder.)

3. Unroll film paper until the end of the actual film is felt. (Open pack and remove films. Remove sheet film from holder.)

4. Attach end of film to reel center or start end of film into free film channel. (Tear away paper and insert pack film in cage slots. Insert sheet film into cage slots.)

5. Wind film into reel by holding with right hand and turning reel with the left (Fig. 45), or push film into free-film reel with the right hand while the left holds the reel.

6. When the rollfilm is almost all in the reel, tear it free from the protective paper, as shown in Fig. 46, and discard the paper.

7. In free-film reels, tuck the free end of the film into the short slot at the opening of the entrance spiral slot. (Place locking band around sheet film cage if any is used.)

8. Put the loaded reel or cage in the tank, and place cover on tank. Now you have completed the loading operation and are ready to proceed with development.

WARNING: These preliminary steps must be done in total darkness in the case of fast panchromatic films; with a faint green light in the case of slow panchromatic films; or with a deep red light in the case of orthochromatic films. It is advisable to make a habit of loading all films in total darkness as a precautionary measure.

9. Take tank into the workroom lighted by daylight or by ordinary incandescent light.

10. Check temperature of developer. This is usually 65°, 68°, 70°, or 72° F; 68° is the most widely

used developing temperature. If a few degrees off, bring the developer to this temperature.

11. Pour developer into tank with one continuous motion.

12. Set timer for the desired developing time, taking into consideration the time required to fill the tank.

13. Shake tank gently to dislodge air bubbles. Agitate the tank at intervals of not more than one minute throughout development. A gentle rotary motion is preferred to violent shaking, as the latter may produce bubbles. **NOTE:** It is highly desirable to make use of a continuous agitator for all film development.

14. At the end of the developing period, pour off the developer as rapidly as possible.

15. Fill the tank with water, rinse fifteen seconds, and empty tank. (If a short-stop is used, pour it into the tank as soon as the developer is poured out, without rinsing.)

16. Pour off water or short-stop.

17. Pour in hypo solution, agitate for a moment or so. (Continuous agitation is not as necessary as in development, but it will do no harm and will often prevent unfixed spots.)

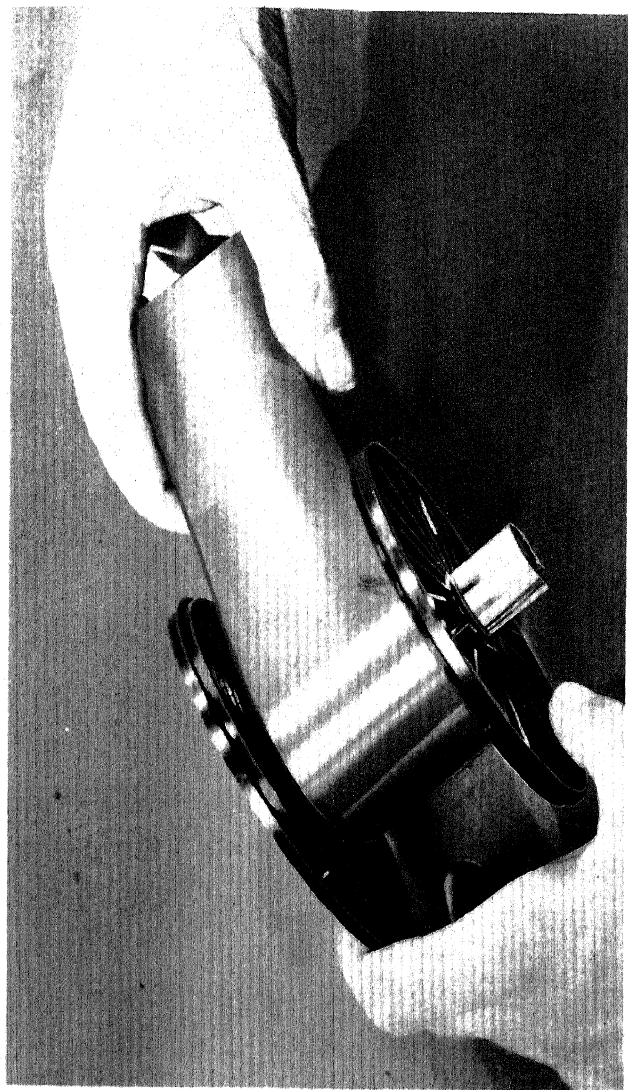
18. At the end of the fixing time remove the cover of the tank and place it in a dish of water.

19. Pour off the hypo.

20. Flush out the tank five times with water. If a hose and small nozzle are available, the water can be forced into the tank bottom and thus do a better job.

21. Set the tank under a faucet to which a hose is attached. Run the hose to the bottom of the tank and open the faucet until the stream has considerable force.

WARNING: Setting the tank under a slow stream of water falling freely into the tank will not do a good job of washing. The hypo remains in the bottom of the tank and the water merely flows into the top and over the tank side.



Eastman Kodak Co.

Fig. 45. Rollfilm is fed into the fixed-film type of reel with right hand as reel is turned with left.



Fig. 46. After rollfilm has all been fed into the developing reel, protective strip of paper is torn off.

22. At the end of the washing time—about fifteen minutes if the five thorough flushings have been used at the start—the film is removed from the reel. (Sheet and pack films are removed one at a time and treated just like rollfilms.)

23. The film is rinsed under running water and both surfaces washed with a wet viscose sponge.

24. Wash the film a second time under running water.

25. Remove surplus water with a rubber squeegee; or by running the film between the fingers (which must be wet); or by the use of viscose sponges.

WARNING: Viscose sponges must not be used too long or they will start shedding small particles which cling to the film, and when the film is dry they are almost impossible to remove.

26. Blot the film by placing it between sheets of special negative blotting paper and running a print roller over it a few times.

27. Strip film from the blotting paper.

28. Attach weighted clip to the bottom of the film.

29. Hang film in a room where there is a current of dry air, not too cool and not hot. It is best to hang the film in a dryer when one is available.

30. When the film is dry, polish both surfaces with carbon tetrachloride or with a film cleaner made for cleaning amateur motion picture films. **NOTE:** Special film coatings can be applied if desired. Some of these do provide a material protection to the film; but if a film has been hardened and is handled carefully after it is dry, no further processing is necessary.

These thirty steps comprise the routine of ordinary film development. Some workers use a preliminary bath of plain water to insure uniform spreading of the developer over the film surface; others use a special wetting agent. These are steps which the beginner may well omit until he learns the basic process.

Although the process sounds somewhat formidable, it is easy and does not take a great deal of time. For example, using a typical film and developer, the timetable would be about like this:

Loading tank, complete operation.....	2 min.	
Pouring in developer.....		15 sec.
Developing time.....	10 min.	
Stop bath.....	5 min.	
Fixing	12 min.	
Flushing five times.....	1 min.	30 sec.
Washing	15 min.	
Washing surface and blotting.....	2 min.	
Drying	45 min.	
Polishing	2 min.	
Total elapsed time.....	94 min.	45 sec.

In short, about an hour and a half is required, with much of the time consumed in washing and drying. It will be noticed that no time is allotted for emptying and refilling the tank except the initial filling. Developing time extends from filling until the short-stop filling. In other words, the tank is actually emptied a fraction of a minute before the time is up so that the short-stop filling will coincide with the end of the developing time. This is because development continues in the film after the developer is poured off. In fact, it really continues for a time after the short-stop is applied, slowing down until it is completely stopped within a minute or less after the tank is filled. When no short stop is used, the development continues at a much slower rate in the rinsed film, and is only completely stopped a short time after the hypo is added.

Naturally no fixed timetable can be set up, because with a given developer the time varies with (a) the film type used, (b) the degree of development desired, and (c) the temperature. Likewise with fresh hypo the fixing time may be decreased. With carefully con-

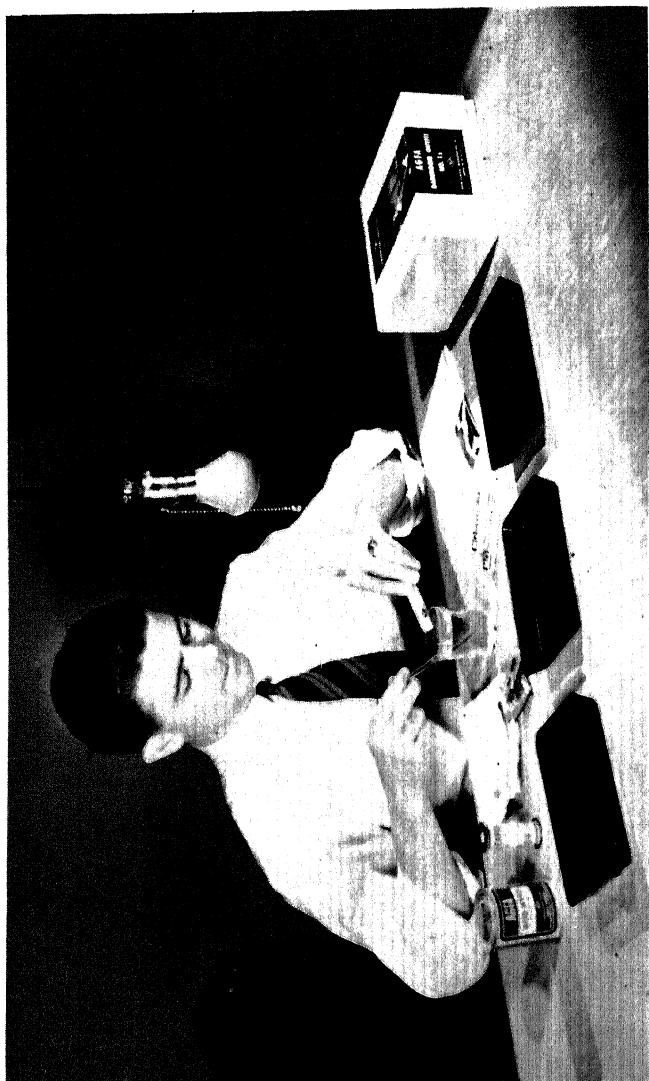
trolled washing in forceful running water the washing time can be cut down. Film will dry faster in a good dryer than it will in an open room. Under actual working conditions the time may vary from about thirty minutes to more than three hours, depending upon the method used.

To make use of the specific factors, let us consider Panatomic-X film developed in two developers, Eastman D-76 and DK-20. With continuous agitation the average time in D-76 will be 12 minutes at 65° F.; with DK-20 the time will be 15 minutes at the same temperature. Thus the total time elapsed will be increased two and five minutes, respectively, over that shown in the time table. This table has been given as a check list, and only to show the general relationship of the times required for the various steps.

In actual practice the actual times will be governed by local conditions and by the process chosen. As has been said, fresh hypo will permit a safe reduction of fixing time to ten minutes if the hypo has free access to the film. Washing may be cut to twenty or even to fifteen minutes if the film is thoroughly flushed to remove all superficial hypo, and then washed in a tank with a stream of water sufficiently forceful to remove all hypo solution as rapidly as the hypo is extracted from the emulsion. Development at higher temperatures requires less time than at lower ones, although unless a special high-temperature developer is used—one containing sulfate, or an alkali-free developer such as amidol—it is always advisable not to exceed 72° F.

Developer Formulas.

Many amateurs and a great many professionals have developer formulas which they prize highly, and which are guarded as secrets of great value. This attitude very closely resembles that of the child which guards



Agfa Ansco

Fig. 47. Standard developers are obtainable in dry form. The beginner need only dissolve them in water.

a "secret." These formulas are nothing at all unusual. In fact, many of them are the result of accident or haphazard experiments, and have given exceptional results in a single instance; but most are generally inferior to standard formulas.

There was once a photographer who knew, as all photographers know, that copying is extremely difficult and that a copy is necessarily flat (although why this is so widely "known" is a mystery, as it certainly is utterly false; copying is easy and it is also easy to increase contrast in a copy as well as to decrease it). This photographer failed in one or two attempts, and finally hit upon a developer which was suggested for developing line-copy negatives—that is, a hard developer. He tried it and got much better results than he had before. Enthusiastically he adopted it for general use. By underexposure and underdevelopment he worked out a schedule which didn't block too badly, and no one could ever convince him that he did not have the secret of a magic developer. That his prints were utterly lacking in quality didn't mean a thing. He could make a crisp copy negative, so the developer simply had to be superlatively good!

Too much emphasis cannot be laid upon the fact that the film manufacturers know the full details of every developer on the market and of thousands which are not on the market. A complex developer originated by an untrained man who can write good publicity may provide a neat source of income to the originator, but it is an unnecessary drain upon the pocketbook of the amateur.

On the contrary, there are some special developers, also very well known to all photographic engineers, which do have merit. For example, a physical developer has many advantages and, of course, many disadvantages as well. They are somewhat difficult to make, so if you want a physical developer and prefer to

buy one ready made, the whole transaction is justifiable.

There are a sufficient number and variety of good formulas provided by manufacturers of film and reputable photo chemicals to fit every conceivable need. It has not yet been shown that any secret developer can produce any effect which cannot be duplicated by one or more of these published and proven formulas.

Another question which arises from time to time is, "What company has the best formulas?" Well, just as in the case of automobiles or clothes, the "best" means the one you prefer. There is no blanket superiority to be found in any one group. Broken down into their basic form, the formulas published by various manufacturers are in many cases so close to being identical that they may be interchanged without difficulty. This shows that the real experts have the same ideas about developers, and it also shows us that they have arrived at a similar conclusion through independent research, so they are probably pretty close to right.

Published formulas may be given in the metric or avoirdupois systems, and may be divided to make any desired total. Therefore, it is desirable to reduce all formulas to a common basis of comparison. This may be done in the avoirdupois system by reduction to grains per ounce, or in the metric system to grams per liter. To compare formulas in the two systems it is necessary to convert one of them to the other system, because grams per liter is on a basis of 1:1000 while grains per ounce is on a basis of 1:437.5. For users of the slide rule it may be added that (grams per liter) $\times 2.19 =$ grains per ounce.

We shall examine some of the more commonly used developers and note the special characteristics of each. These developers are taken from the published lists of Agfa Ansco, Defender Photo Supply Company, and Eastman Kodak Company. This selection does not imply that formulas of other manufacturers are in-

ferior, but to increase the list would only entail unnecessary duplication which space does not permit.

First we have the old favorite, and one which, if it can be kept under control, does provide a negative that exhibits the greatest degree of all desirable printing qualities which can be expected. This is the pyro developer. It stains the negatives, but this is an image stain which adds to the negative value. At times a scum forms which indelibly marks the negatives, and pyro stains the fingers quite badly. Many amateurs have discarded it for the cleaner working types of developer.

There are many variations of the pyro formula, but we shall consider the three-solution formula usually known as the **A-B-C Pyro**.

A-B-C Pyro Developer

Solution 1 (A).	Agfa 45	Defender 1-D	Eastman D-7
Metol.....			110 gr.
Sodium bisulfite.....	145 gr.	140 gr.	110 gr.
Pyrogallol.....	2 oz.	2 oz.	1 oz.
Potassium bromide.....	16 gr.	16 gr.	60 gr.
Water to make.....	32 oz.	32 oz.	32 oz.

Solution 2 (B).

Sodium sulfite, desiccated.....	3½ oz.	3½ oz.	5 oz.
Water to make.....	32 oz.	32 oz.	32 oz.

Solution 3 (C).

Sodium carbonate, monohydrated.....	2¾ oz.	2¾ oz.	2½ oz.*
Water to make.....	32 oz.	32 oz.	32 oz.

*The Eastman formula calls for desiccated carbonate.

Dilution for Use

Tank development

Solution A.....	1	1	1
Solution B.....	1	1	1
Solution C.....	1	1	1
Water.....	11	14¼	13

The above table for mixing is based on "parts" of

any desired volume. Times and temperatures suggested are:

Temperature.....	65° F.....	68-70° F.....	65° F.
Time.....	9-12 min.....	9-12 min.....	11 min.

It will be seen that there is little variation between the first two, even less than is apparent because in tabulating them the formulas have been reduced on the basis of 440 grains to the ounce instead of 437.5. Thus 110 grains indicates $\frac{1}{4}$ ounce and should be 109.4 for extreme accuracy.

Among the favored formulas for general use are those which combine an excess of sulfite with borax, commonly known as borax developers. They are characterized by fine grain, full density, excellent tone values, and general all-around high quality. Among these we find the Agfa 17, the Defender 6-D, and the Eastman D-76.

	Agfa 17	Defender 6-D	Eastman D-76
Metol.....	22 gr.....	29 gr.....	29 gr.
Sodium sulfite, desiccated... 2½ oz. 80 gr.....	3¼ oz.....	3 oz. 145 gr.	
Hydroquinone.....	45 gr.....	75 gr.....	73 gr.
Borax.....	45 gr.....	29 gr.....	29 gr.
Potassium bromide.....	7½ gr.....		
Water to make.....	32 oz.....	32 oz.....	32 oz.

Here the Agfa solution is weaker throughout, except in borax, but includes potassium bromide, which is lacking in the other two.

These two examples should be enough to show that where differences exist between formulas of different origin the difference is consistent, and that basically the formulas are very much alike.

Among the finegrain formulas there are two distinct

types. First there is the group using paraphenylenediamine and adding metol, glycin, or some other reducing agent to obtain the desired potential. The second group is that which gives normal development, but keeps graininess down through etching out a part of the silver of the image. The first group belongs to the "surface" type of developers, and entails certain unavoidable losses in negative quality. The second group retains full gradation with but slight difference, if any, from the degree of graininess produced by the surface type.

The Agfa finegrain formula is the borax type (17) already given, and the 17-M which substitutes sodium metaborate for the sodium tetraborate (borax) of the regular 17. The Defender 5-D formula adds glycin to the paraphenylenediamine. As glycin is one of our best developing agents, it adds considerable quality which would not be expected of a straight p-diamine developer. The formula is:

Defender 5-D Finegrain Developer

Sodium sulphite, desiccated.....	3 ounces
Paraphenylenediamine.....	148 grains
Glycin.....	29 grains
Water to make.....	32 ounces
Develop 30 minutes at 68° to 70° F.	

This is just about as satisfactory a developer as will be found in the paraphenylenediamine group. However, there is one important factor to be considered. Paraphenylenediamine as a developing agent entails some loss of desirable qualities other than fine grain. But it has another quality which, as pointed out by Dr. Edmund Lowe in his book on developers, is of considerably greater importance. It has the power to cause other and more desirable agents to work in a

solution of lower alkalinity than they would otherwise require.

Thus there is an intermediate group of developers widely used for finegrain development which utilize paraphenylenediamine largely for this purpose, and in which the reduction by the p-diamine is, to a certain extent, incidental. Among these formulas may be found the Edwal-12, a high favorite (and rightly so) among those who prefer p-diamine development. The formula :

Edwal-12 Finegrain Developer

Metol	90 grains
Sodium sulfite, desiccated	3 ounces
Paraphenylenediamine	150 grains
Glycin	75 grains
Water to make	32 ounces

There are other formulas supposed to give even finer grain structure, but most of them include one or more ingredients of secret composition. Often the fancy name masks a chemical of common knowledge, and is obtainable from only one source. However, there are a sufficient number of open formulas to meet all our needs.

Among the finegrain developers there is the Eastman DK-20, which makes use of potassium thiocyanate to produce a reduction in actual grain size, rather than in suppressing development in any manner. I have found it highly satisfactory on all 35 mm films, and for developing the tiny Minox films. The small Minox negatives are projected to 40 diameters as routine procedure. The actual test of a developer is that of use in practical work. In this regard DK-20 has never failed me. You may not like it; you may prefer a different

formula; but as far as I am concerned it remains my favorite when big blowups must be made. The formula:

Eastman DK-20—Finegrain Developer

Metol.....	72½ grains
Sodium sulfite, desiccated.....	3 oz. 136 gr.
Kodalk.....	29 grains
Sodium thiocyanate.....	14½ grains
Potassium bromide.....	7¼ grains
Water to make.....	32 ounces

There are two substitutions permissible in this formula. Potassium thiocyanate may be substituted for the sodium salt, and I have had good results by the substitution of either borax (sodium tetraborate) or sodium metaborate for the Kodalk, which has the characteristics of this group of accelerators. The typical time is 20 minutes at 65° F., but this varies with the film to be developed. Kodalk is not borax; therefore, as may be expected in any non-identical substitution, some difference in result may occur. Substitutions are made on weight-for-weight basis and development time is the same, but the developer is more active. Both borax and Kodalk may be increased up to ten times the amount called for in the formula, with corresponding decreases in time. A ten-time borax or Kodalk concentration will cut developing time to 25 per cent of the original time.

A formula is supplied for a replenisher, but developers are cheap and the quantities used are small, so the amateur who wants quality will discard his developer when it has been used one day (or after two or three films have been developed in each pint), and make fresh solutions for each day's work. When making up any type of borax developer, however, it is advisable to add 10 per cent to 20 per cent of a previously



Agfa Ansco

Fig. 48. When rollfilm is to be tray developed, it is advisable to attach a film clip to the end as soon as revealed in unwinding.

used, old bath to the new solution for "ripening" purposes. The conventional borax (D-76) type is kept in perpetual solution by adding fresh solution to the stock as its volume diminishes with use.

Briefly, if you want fine grain, use a moderate to slow film. If you use fast film and then use a superfinegrain developer, you have to give the added exposure anyway. Give **normal** exposure, and then even in

borax you will usually get a better grain pattern than the other way round.

There are times, such as in copy work, where line copy is to be reproduced. Then we want a contrast developer which will produce fine, clean-cut results. There are several such formulas, among which we find:

Eastman D-8—High Contrast Developer

Stock Solution.

Sodium sulfite, desiccated.....	3 ounces
Hydroquinone.....	1½ ounces
Sodium hydroxide.....	1¼ ounces
Potassium bromide.....	1 ounce
Water to make.....	32 ounces

For use, take 2 parts of stock solution and 1 part of water. Develop about 2 minutes at 65° F.

Agfa 70—Hydroquinone Caustic Developer

Solution 1.

Hydroquinone.....	¾ oz., 40 gr.
Potassium metabisulfite.....	¾ oz., 40 gr.
Potassium bromide.....	¾ oz., 40 gr.
Water to make.....	32 ounces

Solution 2.

Sodium hydroxide (Caustic soda).....	1 oz., 90 gr.
Water to make.....	32 ounces

Mix equal parts of Solutions 1 and 2 for use, develop not more than 3 minutes at 65° F. If potassium hydroxide is preferred, use 1½ ounces, 80 grains, instead of the quantity shown for sodium hydroxide.

There is always a seasonal interest in hot-weather developers. It is far better to reduce the temperature of solutions, or to wait for a cool evening. However, when development must be done under high-temperature conditions, there are three ways to do it which are widely used: (A) Use a concentrated developer,

develop a short time, fix quickly, and wash as rapidly as possible. (B) Use a developer such as amidol, which does not require any accelerator. (C) Add sodium sulfate to the developer. This last method is the basis for some commercial developers which are advertised to work at any temperature. Almost any satisfactory developer can be made into a high-temperature developer by adding five per cent by weight of dry sodium sulfate to the working solution, but only the best CP or Reagent grade of sulfate should be used. Otherwise the addition might change the reaction too much toward the acid side. Among the tropical developers we find:

Agfa 64—Tropical Developer

Metol.....	36 grains
Sodium sulfite, desiccated.....	$\frac{3}{4}$ oz., 40 gr.
Hydroquinone.....	95 grains
Sodium carbonate, monohydrated.....	$\frac{1}{2}$ oz., 15 gr.
Potassium bromide.....	15 grains
Water to make.....	32 ounces
Use undiluted, develop 3 to 4 minutes at 65° F. or 2 to 3 minutes at 85° F.	

The Eastman tropical formula is based upon the sulfate idea, and makes use of the general borax type of combination. In this formula notice the inclusion of bromide which is uncommon in developers of the conventional borax type.

Eastman DK-15—Tropical Developer

Metol.....	82 grains
Sodium sulfite, desiccated.....	3 ounces
Kodalk.....	$\frac{3}{4}$ ounce
Potassium bromide.....	27 grains
Sodium sulfate, desiccated.....	$1\frac{1}{2}$ ounces
Water to make.....	32 ounces

(SEE NEXT PAGE)

Tank development 9 to 12 minutes at 65° F. or 2 to 3 minutes at 90° F. For development below 75° F. the sulfate may be omitted, when the time becomes 5 to 7 minutes at 65°. For tray use the time is reduced about twenty per cent.

There are two developers in the paraminophenol group which are used for tropical development. First there is the one published by the British Journal; the formula is as follows:

Sodium sulfite.....	1 ounce
Paraminophenol hydrochloride.....	60 grains
Sodium carbonate, monohydrated.....	1 oz., 15 gr.
Sodium sulfate	375 gr. to 1 oz., 350 gr.
Water to make.....	20 ounces

All sodium salts are in dry form. The sulfate content is changed with temperature, the minimum amount for 80° F., and the maximum for development at 95° F. A similar developer for finer grain is:

Sodium sulfite, desiccated.....	3¼ ounces
Paraminophenol base.....	50 grains
Sodium sulfate, desiccated	1 oz., 250 gr.
Water to make.....	32 ounces

The grain structure becomes coarser as the temperature rises, but even at 95° F. this developer will produce a negative suitable for considerable enlargement.

The use of amidol is more popular in Europe than here, and it is not limited to high-temperature work. As a rule, it is used as a tray developer for development of ortho films by visual inspection. Amidol requires no accelerator, but unfortunately it has very poor keeping qualities, so that it is ordinarily mixed immediately before use in quantity just sufficient for the work in hand.

Amidol is used by some of our best-known salon

exhibitors for both negative and print development. It gives an excellent negative, and once its use has been mastered, other agents are rarely used. The one disadvantage is that as a time-and-temperature developer it has not proven as amenable to control as have the more common agents.

One favored formula in England is the neutral form. This is made from a stock solution prepared by dissolving twenty-five grams of dry sulfite in a liter of water. To prepare a developer, this solution is taken in sufficient quantity, say one hundred cubic centimeters. A few drops of alcoholic solution of phenolphthalein are added. The alkaline solution will then turn pink. A five per cent solution of potassium metabisulfite is added drop by drop until the color barely disappears. The solution is then neutral. To each one-hundred cubic centimeters of this neutral sulfite solution are added a half gram of amidol and five drops of a ten per cent solution of potassium bromide.

For those who do not wish to go to so much trouble, the ordinary amidol solution may be prepared according to this formula:

Amidol Developer

Amidol.....	60 grains
Sodium sulfite, desiccated.....	1 oz., 40 gr.
Potassium bromide.....	12 grains
Water to make.....	20 ounces

Although we are not concerned with paper developers, it may be of passing interest to mention the "teaspoon" formula, which provides a quick method of compounding the developer for prints. To make up a 24-ounce solution, dissolve two level teaspoonsful of sodium sulfite and one level teaspoonful of amidol in about 16 ounces of water. Add 10 grains of potassium bro-

mide, then add sufficient water to make 24 ounces. This is further simplified by using 5-grain potassium bromide tablets, which can be obtained from the druggist. The need for a balance or measuring device is eliminated, and a batch of developer can be prepared in a few minutes. A quart jar provided with an adhesive-tape marker at the 24-ounce level makes a good mixing container.

Another simple method of preparing amidol for prints is to keep on hand a stock solution containing 4 ounces, 180 grains of sodium sulfite and 60 grains of potassium bromide in 64 ounces of solution. To prepare a working solution, dilute a portion of the stock with an equal amount of water, and add 20 grains of amidol to each 8 ounces of diluted stock solution.

It is significant that in years past a highly favored developer was the "Universal" type which was used for all negative and paper work. Such terms as "Universal" are not in favor in this modern age of specialization, but the developers under new names are still with us simply because they are good, soundly formulated developers for normal use. They are not finegrain, nor are they particularly good at rendering delicate tone gradation, but are still among the best paper developers.

Agfa 103—Universal Film and Paper Developer

Stock Solution	
Metol.....	50 grains
Sodium sulfite, desiccated.....	1½ ounces
Hydroquinone.....	¼ oz., 55 gr.
Sodium carbonate, monohydrated.....	2½ oz., 35 gr.
Potassium bromide.....	18 grains
Water to make.....	32 ounces

Dilute one part of Stock Solution with two parts water and develop about 5 minutes at 65° F. Use same dilution and up to 1 to 4 for bromide papers.



Agfa Ansco

Fig. 49. The film is held by metal clips, and see-sawed back and forth through the developer for the correct period of time.

Eastman D-72—For Film and Paper**Stock Solution**

Metol.....	45 grains
Sodium sulfite, desiccated.....	1 ½ ounces
Hydroquinone.....	¼ oz., 65 gr.
Sodium carbonate, desiccated.....	2 ¼ ounces
Potassium bromide	27 grains
Water to make.....	32 ounces

Dilute one part of Stock Solution with two parts of water, and develop about 5 minutes at 65° F.

In the two preceding formulas we see a difference which is more apparent than real. This is in the amounts of carbonate. The Agfa formula calls for monohydrated carbonate and the Eastman for the desiccated form. This is a subject which we shall deal with in some detail a little later.

There are some miscellaneous formulas which are of value and these we shall present for what they are worth for occasional use.

Eastman D-82. A high-energy developer for known underexposures. Here we have a practical application of the basic principle already discussed; namely, that while you cannot develop an image not recorded upon the film, many developers fail to develop all the image which has been recorded! So here we have a developer which apparently will do the impossible.

Warm water (not above 125° F.).....	24 ounces
Wood alcohol (not denatured alcohol).....	1 ½ fl. oz.
Metol.....	200 grains
Sodium sulfite, desiccated.....	1 ¾ ounces
Hydroquinone.....	200 grains
Sodium hydroxide.....	125 grains
Potassium bromide.....	125 grains
Cold water to make.....	32 ounces

This developer will keep a few days in a full bottle,

but not more than two hours in an open tray. Develop in a tray for about 5 minutes at 65° F. Discard after use.

Agfa 90. For high contrast, but not as great as the extreme contrast of a caustic developer, this formula has proven very good:

Metol.....	75 grains
Sodium sulfite, desiccated.....	1 oz., 150 gr.
Hydroquinone.....	88 grains
Sodium carbonate, monohydrated.....	1 oz., 150 gr.
Potassium bromide.....	45 grains
Water to make.....	32 ounces
Develop 4 to 6 minutes at 65° F.	

Metol Developer. For extremely soft gradation and fine detail, metol alone may be used. This formula has been found satisfactory, particularly as the time of development may be changed within wide limits to control the result. Give full exposure and try an experimental control film at thirty minutes as a starter.

Metol.....	75 grains
Sodium sulfite, desiccated.....	275 grains
Potassium bromide.....	16 grains
Sodium carbonate, desiccated.....	200 grains
Water to make.....	32 ounces

Although lantern slides and transparencies are forms of positives and as such have no place in this discussion, the positive transparency is often used as an intermediate step in the production of duplicate negatives and in paper negative work. For that reason we shall include three formulas designed particularly for use in positive transparency work.

The positive from which a negative is to be made

must have soft gradation. An image of the usual positive type is too hard, and in the transfer the negative will lose much of its gradation. Therefore, a soft working positive developer is best for this purpose. Such a developer is:

Positive Pyro-Soda

An A. B. C. formula

Solution A.

Pyrogallol.	100 grains
Sodium sulfite, desiccated	400 grains
Citric acid	50 grains
Potassium bromide	100 grains
Water to make	10 ounces

Solution B.

Sodium carbonate, monohydrated	320 grains
Water to make	10 ounces

Solution C.

Potassium bromide	100 grains
Water to make	10 ounces

Make up 1 part each A and B, and add a volume of water equal to these 2 parts. For more brilliant results use 1 part of A, B, and C, and 1 part water, or any intermediate mixture of C and water. Time 4 to 8 minutes according to the amount of solution C used.

For microfilming (greatly reduced copies of records, books, papers, etc.) the following Agfa formula will provide high contrast and good definition.

Agfa 22—Title Developer

Metol	12 grains
Sodium sulfite, desiccated	1¼ ounces
Hydroquinone	120 grains
Sodium carbonate, monohydrated	1¾ ounces
Potassium bromide	75 grains
Water to make	32 ounces

Time for positive emulsions, 5 to 8 minutes at 65° F.

For straight positive film development, Agfa 20 is good:

Agfa 20—Positive Developer

Metol.....	30 grains
Sodium sulfite, desiccated.....	370 grains
Hydroquinone.....	60 grains
Sodium carbonate, monohydrated..	270 grains
Potassium bromide.....	30 grains
Water to make.....	32 ounces
Develop 3 to 4 minutes at 65° F.	

We might go on and on, filling hundreds of pages with formulas, all of them workable, many of them excellent, but to what purpose? We have no reason to include special developers for X-ray and photomicrography, no need to list the multitude of developers used for movie work, no reason to include any special-purpose developers. But within closer limits than that we still have multiplied hundreds of formulas. We have examined a series of typical formulas, all of which are easily available to any amateur.

Should you happen to be interested in additional formulas they are to be found in the publications of Agfa, Defender, Du Pont, Eastman, Gevaert, Ilford, and many others. The photographic publications of this country and of Europe publish a multitude of them. Photographic reference books have them by the dozens. But you will be well advanced in photography before you can advantageously exhaust the possibilities of the formulas supplied gratis by the film manufacturers.

Carbonate Conversion.

In the preceding formulas certain things will have been apparent. Some we have discussed in a theo-

retical manner and some we have not mentioned. First of all, there is that problem of the sodium salts, or the "sodas" as they are more familiarly known. We find the anhydrous and crystal form of the sulfite and sulfate, and the carbonate in three forms: crystal, monohydrated, and anhydrous.

When salts crystallize, the formation of the crystal makes it necessary to include a certain amount of water. This is known as the **water of crystallization**. It is obvious that if a certain crystal, say sodium sulfite, has half its weight in water, then it would be necessary to use twice the weight of that crystal form as compared with a dry (desiccated or anhydrous) form.

British formulas are often given in terms of the crystal salt, which is rarely the case in our own country. When this is not the case, the British call for the anhydrous carbonate while most of our own formulas call for the monohydrated form which is rarely used in England. There is quite a controversy about the two forms of the dry carbonate, many chemists claiming that the monohydrated form remains stable for a longer period and that it will not cake as easily when poured into water for mixing. Ordinarily Eastman formulas call for the anhydrous carbonate, and other formulas the monohydrated.

We are not concerned with the actual superiority of either form, if indeed such superiority exists at all, but we are definitely concerned with the proportions of strength of the various forms so that we can alter any formula calling for a specific form to that which we happen to use. In the case of the sulfite this is easy. If a formula calls for the crystal salt, use just one-half that amount of the dry form; or conversely, if only crystals are available, use twice as much as the amount of dry salt called for in the formula. Sodium sulfate is not so easy to convert; seven parts of the crystal are equivalent to three parts of the dry form.

Crystalline sodium carbonate must be used in the ratio of 2.86 to 1 for conversion to the anhydrous form; 2.43 to 1 for conversion to the monohydrated form; and 1.18 to 1 for conversion of the monohydrated form to the anhydrous. That is, if you have a formula calling for 1 ounce of anhydrous carbonate you would use 2.86 ounces of the crystal, or 1.18 ounces of the monohydrate.

If you have a formula calling for 1 ounce of the monohydrated form you would use 2.43 ounces of the crystal, or 0.84 ounces of the anhydrous.

If you have a formula calling for 1 ounce of the crystal form you would use 0.4115 ounce of the monohydrated, or 0.3496 ounce of the anhydrous form.

Percentage of Accuracy.

This, of course, calls for another discussion of the limits of accuracy in weighing out photographic chemicals. For ordinary purposes, an accuracy of five per cent is quite enough, although greater accuracy is advisable when practical. Thus, if you reduce a formula as in the carbonate examples just given, and you find you should use 0.3496 ounce of the anhydrous form, you will naturally pay no attention to the fourth decimal place. In fact, you will round this off into 0.35 ounce. Moreover, you will consider one grain of weight as $1/440$ of an ounce instead of $1/437.5$ of an ounce. Then $1/100$ or 0.01 ounce will be 4.4 grains, and this multiplied by 35 gives you 154 grains—the anhydrous equivalent of one ounce of crystalline carbonate. That the actual equivalent is 152.95 grains is not significant, as the difference of 1.05 grains is an error of less than one per cent.

It is hardly practical to try to weigh halves and quarters of a grain on the ordinary photo scales, and usually there is an over- or under-balance of greater

error than this. It pays to be careful, but the use of an analytical balance in the darkroom is a waste of time, money, and patience.

Use of Various Alkalis.

There is another point which puzzles many amateurs. This is the use of hydroxides, carbonates, metaborates, phosphates, borax, and other alkalis. Why not use just one? In common with many other chemical reactions, the solution's degree of alkalinity has a great effect upon the result. To use a more accurate term, the **hydrogen ion concentration** (usually abbreviated as the "*pH*") is of great importance. In the *pH* scale 7.00 represents the neutral reaction of pure, distilled water. As the scale values decrease the reaction denoted is acid; as it increases the reaction is alkaline. Thus, 6.00 is weakly acid, 3.00 or 2.00 is strongly acid; 8.00 is weakly alkaline, and 9.00 or 10.00 is strongly alkaline.

The approximate reactions of various accelerators when used in the normal working solutions are:

Pure water, neutral.....	7.00
Borax, weak alkali.....	8.00 to 9.00
Metaborate, moderately weak.....	9.00 to 10.00
Carbonate, moderate.....	9.50 to 10.50
Hydroxide, strong.....	10.00 to 12.00

The hydroxide is used for extremely energetic development with a reducing agent of low potential, such as hydroquinone, when extreme contrast is required. Although the formula is well known, the actual developer has limited application.

Carbonate is a salt of the comparatively weak carbonic acid, but in solution it produces bicarbonate (acid) and hydroxide in small amounts. It continues

to deliver **small** amounts of the active hydroxide over a considerable period of time, this reservoir action making it particularly well fitted for photographic purposes.

Recently borax has come into favor, particularly where a comparatively low contrast negative can be used. It would perhaps be more truthful to say "where a high contrast negative is not necessary," for the borax developers produce quite a satisfactory contrast, but not an excessive one. Borax has a reservoir action also, and exhaustion or even the addition of acid in small amounts does not make much change in the reaction of the solution until all the borax has been neutralized.

One reason for the substitution is that borax does not form carbon dioxide with the resulting formation of blisters between film and base, as happens so often in hot weather when a carbonate developer is used. Nor does borax cause the formation of the aluminum scum which is often precipitated upon negatives in a weak fixing bath (of the alum-acid type) following a carbonate developer. One objection to the borax acceleration is the fact that there is a limited capacity caused by the low solubility of the borax. Weight for weight, it requires about ten times as much borax as carbonate to provide equal development energy, and such quantities are difficult if not impossible to dissolve.

These opposing characteristics of carbonate and borax have led to the use of an intermediate alkali. Eastman has introduced their Kodalk, and other manufacturers advocate the metaborate. The activity factor is about midway between carbonate and borax, but the intermediate alkali does not blister or form scum, so the greater advantages of borax are retained together with at least part of the greater activity of carbonate.

The belief is often expressed that Kodalk and sodium metaborate are simply borax under "fancy" names. This is definitely not true. The fact that borax and metaborate are both sodium "borates" is often cited as proof, the lay amateur not realizing the significance of the chemical prefixes. The tetraborate (which is borax) is decidedly not identical with the metaborate used for an intermediate developer.

Laboratory Routine.

There are certain phases of development which you must decide for yourself. Are you going to keep stock solutions which are to be diluted for use? Are you going to keep working solutions for repeated use until exhausted, or are you going to make fresh solutions for each development period? The latter is advisable ordinarily, but in the case of the borax developers it is not only permissible but advisable to keep the working solution on hand and to fill the bottle every time it becomes one-quarter emptied through spillage and film absorption loss.

Whatever you decide, you must provide containers. The average amateur laboratory will be well fitted with a one-gallon bottle for hypo and a half-gallon bottle for the negative developer if borax is used. If fine-grain work is to be done, the developer can be made up a day or two in advance, stored in a quart bottle, and then discarded after two or three films are developed in it. You will not get the best quality if you use a "replenisher" because of the by-products which are always increasing in concentration in the working solution.

Make it a habit to clean up all paper and other debris which accumulates before you start each period of development, or immediately after it is done. Cleaning up after developing leaves the workroom neater,

but if you work at night it means extra work when you are tired. Of course, if you work in the kitchen or bath, it is essential that cleaning up follow immediately after developing.

A quick but thorough rinse is sufficient to clean metal or plastic tanks if they have been used as a container during film washing. Tank covers placed in a vessel of water as soon as removed from the tank may also be set aside after a thorough rinse. Stock bottles should be rinsed if any solution has run down the sides.

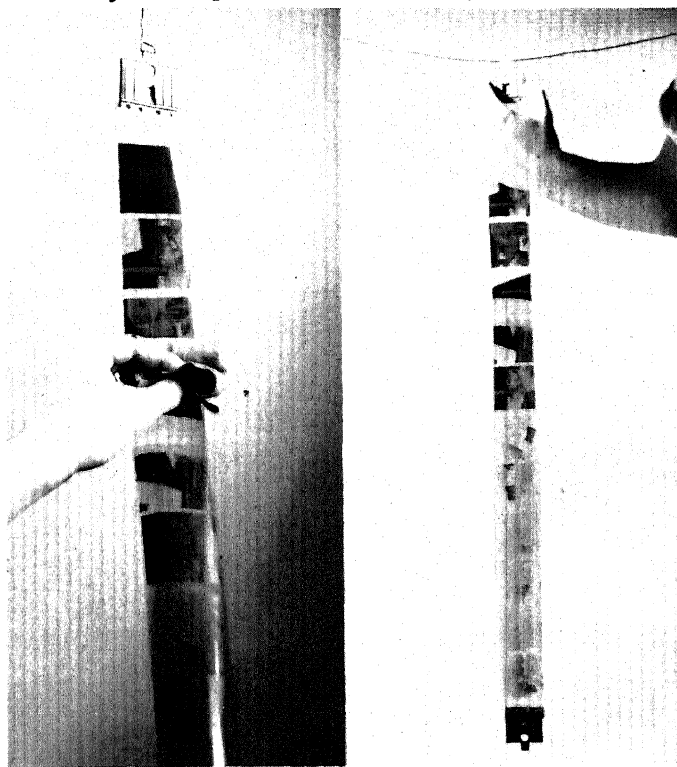
Set up a routine, doing each step in its turn, and soon you will get the habit of developing so that you rarely make a mistake. One habit to form is the removal of the tank lid as soon as fixing is completed. If you develop the habit of covering the tank for washing, you will sometime make a mistake and lift the cover from a tank which is still in the developing stage.

Solutions which are kept in use should be checked carefully. Any which show sediment should be filtered. A check should be kept on the number of films developed in a given solution, although in the continuous solution of a borax developer this need not be done. Hypo should be checked for clarity and tested for exhaustion unless it is discarded as a matter of routine while still comparatively fresh.

Glassware should be cleaned carefully and flushed repeatedly with water. Any discoloration or brownish stain in the glassware is evidence of lack of cleanliness. A workroom may be spotlessly clean and win the approval of a good housekeeper, yet still be far from clean chemically. To keep your equipment chemically clean means that any chemical which comes into contact with any equipment is thoroughly cleaned off before putting that equipment away.

For example, you will often see a balance so corroded and stained that the beam cannot be read, and

the balance is sluggish. I have an ordinary photo balance worth about four or five dollars which is now more than ten years old. It shows some signs of use, but the pans are still polished, the bearings free, and the beam perfectly legible. No particular work was necessary to keep it in this condition, but in addition



Agfa Ansco

Fig. 50. Washed film is wiped with wet viscose sponge or chamois (left), and then hung up to dry in a current of warm air (right).

to superficial cleaning at every use, the balance was dismantled and thoroughly cleaned about twice a year. Similarly, other equipment is given a thorough semi-annual cleaning, with the result that very few equipment replacements are required.

This is not a case of neatness for its own sake—far from it. It is simply because a lack of such cleanliness is going to produce an untold amount of specks, spots, stains, and other unwanted results in your negatives. Cleanliness is one automatic insurance of better quality than you expected.

Checking Results.

In a later chapter we shall discuss the art of reading a negative, but even now you will realize that the processed negative must tell its own story. If the negative is not right, the fault has been either in the exposure or the development. The set of nine negatives will enable you to spot errors of exposure, which means greater or less density, and about everything else—high contrast, low contrast, scratches, spots, blisters, stains, and so on. Dust in the camera may cause spots, and there are some other minor faults not originating in development, but aside from exposure errors, the great majority of faults do originate in development. Of course, we eliminate such gross mechanical errors as lack of focus, movement of subject or camera, holes in camera, fingers over the lens, and so forth. Such errors are inexcusable in anyone except the beginner.

So check your negatives as soon as they are dry (Fig. 51). Locate every fault, and if you do not know what caused it, find out. Chapter XII contains a checklist of negative errors for reference. But in the meantime, remember that every mistake is of value to you provided you determine its origin and do not repeat it.



Eastman Kodak Co.

Fig. 51. As soon as the developed negatives are thoroughly dry they should be examined very carefully and checked for errors.

Time and Temperature.

Never, never forget the unalterable relationship which exists between time and temperature. The higher the temperature the shorter the time for development. Do not guess at either time or temperature, but make use of a reliable thermometer and an equally reliable timer. Guessing at these factors is even worse than guessing at exposure, for you have no featherbed of latitude to land on in case of error.

There is no definite scale of temperature-time relationships, as this varies with the emulsion being developed and the developer being used. Fortunately, most manufacturers now supply graphs which give this information. As an example, the following data concerning certain Agfa formulas given in this chapter show the amount of change in time to compensate for definite temperature changes.

Developer Number	Percentage increase or decrease in developing time at temperatures below and above 65° F.		
	60° F.	70° F.	75° F.
17	+50	-25	-50
20	+50	-30	-50
45	+30	-25	-40
64	+60	-18	-30

The corrections are in **percentage** of the normal time as given with the formula for development at 65° F. Note that as a rough average a drop of five degrees indicates an increase of fifty per cent in time, a rise of the same amount; that is, five degrees calls for a decrease of twenty-five per cent and that a rise of ten degrees calls for cutting the development time in half.

Here is the real reason for many of the great variations in development time reported by various amateurs using the same formula. One will heat a developer

to reach 65° F.; another will cool it, and both neglect to consider the cooling and heating effects, respectively, which follow filling the tank. If you are at all suspicious about your actual developing temperature, take the temperature of the solution **after** developing is complete, and compare it with the temperature at the start.

Second in importance only to correct temperature is the maintenance of that temperature throughout the developing process! In many cases this will prevent reticulation, a serious and common fault which will be discussed in the chapter devoted to the discussion of fixing, washing, and drying.

SPECIAL METHODS IN DEVELOPMENT

V.

Special Methods in Development

PHOTOGRAPHY is a strange mixture of science and craft—definitely an art in the broader meaning of that word. It is almost medieval in this respect, for in no other field since the days of the alchemists have science, skill, theory, superstition, and absurdity been blended into such a successful whole. It is fortunate that while being unbelievably delicate in its reactions, it is not, chemically speaking, very critical. Because of this fact we are reducing the scientific factors to a more or less mechanized basis, which, after all, is a scientific basis.

One of the cornerstones of science is the conviction that "like causes produce like results." This is true in photography as well as in other fields of science. The difference is that while imperceptible changes in causes will produce quite definite changes in results, a very wide change in cause will still produce a usable result.

The materials we use, both the sensitive emulsions

and the apparatus, are not precision materials compared to those used by the research scientist. They are merely "commercial grade." That is, two lenses may show a slight variation in focal length when supposedly they are identical. Shutters will vary in their speeds; even the same shutter will vary under different conditions. Emulsions are not identical from batch to batch, and they, too, undergo a change with age. Therefore, like that of the machinist, our work is limited by two extremes, but between these limits of tolerance we may have any variation.

Controlled Development.

The measurement of exposure has been mechanized. So, too, has basic development; but in fact there is a lot of skill demanded in controlling exposure, and the process of development is one step in the production of a photograph where skill can be given unlimited scope. Mechanized development will serve adequately for casual record shots, but for photographs of any higher quality, more or less control must be exerted over development.

Development may be controlled to produce a definite type of negative (for example, finegrain—Fig. 52), or it may be controlled to produce a definite reproduction of a specific subject (for example, emphasis of contrast—Fig. 53). News work, which demands a print in less time than many development processes require, cannot be performed without special high-speed development. Motion-picture development, which demands uniformity throughout thousands of feet of film, presents a problem that is solved in a quite different way. If the tonal relationship of the original must be exactly reproduced in the negative, physical development is often used. If there is an unavoidable, extreme contrast in the original, the negative may be



Fig. 52. Enlargement from a small negative developed to produce fine grain. There are developing processes to meet every need.

developed while squeegeed face down upon a glass plate. In short, there are development processes to meet almost any and every need.

The point is that these developers are not like costumes which are hung in the closet to be chosen by the whim of the moment. Development is the point at which the picture is often won and may so very easily be lost. Developing technique is chosen for a very definite purpose, and if you are not sure just what you want to do, you had best stick to the film manufacturer's recommended formula.

There is one thing which you must remember if you are to avoid confusion. When speaking of various developers we do not mean the several dozen different trade names under which developers are sold. Most of these developers are simply standard formulas made up and sold under a distinctive name. If you fully understand that these developers are standard, and that they do not possess any properties better than the standard formulas; and if then you prefer to use them because they are more convenient, and because they are (usually) made by skilled workmen from chemicals which are fresh and of good quality, then you are fully justified in using them.

But do not use prepared developers because you imagine they have marvelous properties which you cannot get in any other developer. I once heard two amateurs arguing heatedly about the qualities of two prepared developers. Each said the other's developer was worse than worthless and that his own was superlative. The point is that it happened that these two developers were put out by competitive firms and for all practical purposes were identical!

You'll find the advanced amateur, who should know better, doing the same thing. I recall one true example. This photographer had done quite a lot of work which was widely known. He ordinarily used

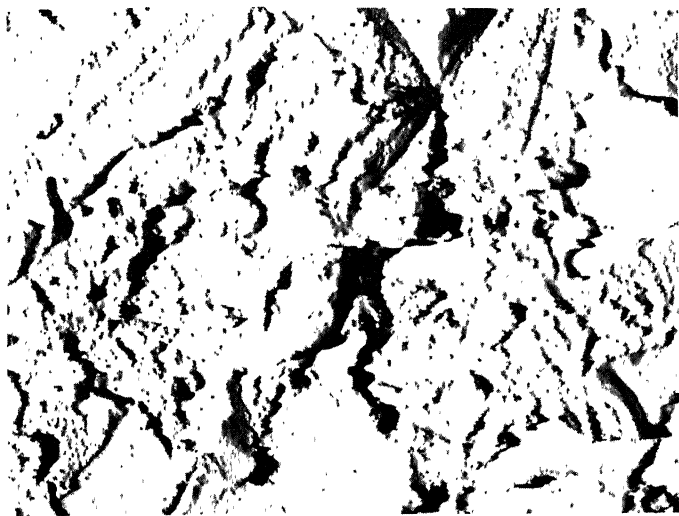


Fig. 53. Print made from a negative developed to exaggerate contrast and thus emphasize the rough texture of the stucco.

developer A because it was dependable and convenient. He did all types of work, and finally got deeply interested in night photography. With practice he developed skill in this specialized field, but of course the negatives were never quite what he wanted. A friend kept urging him to try developer B, but he just laughed and said he guessed that "soup" was "soup."

One day the two went out for a Sunday hike, taking their cameras. It was an ideal day, and both shot up a couple of rolls of film. On the way home they stopped at the friend's house, and he handed our hero a bottle of developer B and urged him to try it. To please the friend our man developed his films in B and they were excellent. They were much better than he had been getting. Being impulsive, he dumped all his A and

went in for B. But he never thought, for a long time, that his B negatives had been exposed under ideal conditions, and that his night negatives demanded the utmost to make them even presentable. He began to awaken when he found his new night negatives developed in B just about the same as his old ones which he had developed in A.

It is unfair to compare developers unless a strip of film is uniformly exposed throughout by making repeated exposures of the same subject, and this film used as a test. Each developer must be equally fresh, each must be used exactly according to instructions as to time and temperature, and final results must be checked by actually making enlargements. Then and only then have you a basis for discussion.

We have already stated that emulsion manufacturers with unlimited research facilities available have determined the best developers for their products. Not only this; they have realized that emulsions are used for different kinds of photographic work, and have provided a variety of formulas for these various applications. Each of these formulas is designed to give the best possible results in every respect.

It happens that in photography we have a process which can be likened to a sheet of rubber. If we stretch it in one direction it becomes narrower in the other. In other words, we can go to extremes in any one direction and accomplish wonders, but it is always at the expense of other qualities. Therefore, unless there is some very special reason which permits this sacrifice, any special developer must be made up with the thought of still keeping the balance as nearly perfect as possible.

The negative has several characteristics:

Contrast	Density
Resolving power	Graininess
Detail	Color

Gradation

Of these, all but gradation and color are inherent in the emulsion, and even gradation is inherent to a considerable degree. Therefore, the best we can hope to do in the matter of development is merely to try to enhance the natural qualities of the emulsion. An inherently coarse-grained emulsion will give more grain in a finegrain developer than will a finegrain emulsion developed in a caustic alkali.

More About Graininess.

The first step in any specialized work is to select the emulsion best suited to that work. In biblio copying or microfilming, for example, books, documents, newspapers, etc., are photographed upon negatives which measure 1 x 1½ inches. They are projected back to their original size with sufficient definition often to be even more legible than the original. Yet these negatives are developed in a fast-working, alkaline developer which would ordinarily be considered as worthless for finegrain work. The explanation is that the film used is a slow, contrasty, finegrained emulsion of inherently high resolving power (see Fig. 54). Even when half-tones are copied, the areas of uniform tone do not show graininess when prints are made on glossy paper and ferrotyped.

We have already discussed the subject of graininess in Chapter II. There is not much to be added to the statements made there, except by way of elaboration. In the first place, the matter of grain has been made the pivotal point in miniature photography, but if ever a "bogey-man" existed it is this subject. The amateur will do well simply to forget it and worry about grain when it really becomes a nuisance.

When does grain become objectionable? Well, it's bothersome in a ferrotyped print when it persists in the reproduction after it has been broken up by the

half-tone screen; for surely there are few who make glossy prints for any purpose other than reproduction.

Graininess is objectionable when it becomes obvious through having a structure larger than the unit structure of the paper surface used. This means that

<p>Home</p> <p>Times. hundreds rial Day ward his utation, 206 High the John died to- r friend, failed to his front the pa- as they n the re- Ward, had</p>	<h1>ON MEMORIAL DAY</h1> <p>Continued From Page One</p> <p>armed forces of the Union in the Civil War marched four blocks. For the first time this year each Civil War marcher was past his ninetieth year. Last year thirteen Union men marched and ten years ago 150 paraded. Twenty-five years ago more than 1,800 were in line.</p> <p>The twelve aged men sat in the bright sunlight on benches along the curb at Eighty-sixth Street when the first marchers went by. They were to head the first division</p>	<p>"Old Gun and the Veterans the guard stand. A Union V acted as Spanish marched their bar war with Time in The thi Veterans United S First Cla Drum an drum-ma Massed</p>
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Fig. 54. Enlarged section from 1x1½-inch microfilm negative on which entire eight-column page from a newspaper was recorded.

the rougher the paper the greater amount of grain will be tolerable.

Graininess is objectionable when the pattern is so lacking in uniformity that it produces small cloud-like shadows on the print.

Graininess is objectionable when it produces actual "freckles" over the face of the print.

Graininess which is revealed as a uniform "egg-

shell" texture is more highly desirable than a print which has no structure whatsoever, because in all nature there is no such thing as a void. Every artist, every pictorialist, has come to recognize the fact that among all technical factors, texture has a high place. One thing which has kept the miniature photographer in a class apart is the fact that in sacrificing quality he actually has succeeded in making prints so devoid of grain that they appear highly artificial. No prints in a really great salon, not even the contact prints, are so completely devoid of structure.

The challenge was issued years ago and it has never been forgotten, so that now the standard of miniature technique is an absence of graininess. If there is no grain in a print, though it lacks every other desirable quality, many persons consider it a good print. On the contrary, if it is an excellent print, which shows a delicate egg-shell texture, they consider it as worthless because it does show grain.

Yes, I, too, have had trouble with grain. Often I have found it necessary to use rough-surfaced paper, etching screens, bolting cloth, and other devices to break up the monotonous emptiness of tones produced by an inherently finegrain film.

As an exercise in technical control, grainless enlargements upwards of twenty or twenty-five diameters can be made, but it should not be done when making a print for any pictorial purpose.

Do not misunderstand—the print should not lack **definition**. A soft-focus photograph is the hardest photograph in the world to make correctly. Usually the soft-focus photograph is just a "bowl of mush." That isn't the point. It is possible to go so far in the other direction that objects appear to have been cut out and pasted on the background, although you will probably not encounter that in anything but a contact print. The true point is that grain is a part

of the image, and it is desirable rather than otherwise until it passes the low limit of visibility and reveals itself as a pattern of spots instead of a recognizable but indefinite textural pattern.

Therefore, the problem in practical negative making is not grain elimination; rather, it is one of grain control.

Finegrain Developers.

As a rule, caustic alkaline developers produce a grain pattern much larger and more irregular than the inherent pattern of the emulsion. This is caused by a physical breakdown of the gelatin structure, permitting previously isolated grains to come into contact and thus become a single unit, where before there were two or more.

Carbonate developers induce too great a degree of swelling, and so permit certain grain migration. Under some unusual circumstances it is great enough to produce visible image distortion; that is, a line edge may lose its definition, or a boundary between tones may become very slightly blended.

Developers using the weaker alkalis do much to keep the original grain pattern of the emulsion, even though the actual shape of individual grains is altered. It is understood, of course, that there will always be a certain amount of breakdown during development, but we are now concerned only with that which occurs in sufficient volume to affect the visual quality of the image.

Because of the limited physical effect of such developers, they are often included in the finegrain group, particularly in Europe. As a matter of strict fact, these developers using the borates (and phosphates) as alkalis are more deservedly popular for their ability to preserve the utmost delicacy of tonal gradation. Ex-



Some pictures are improved by slight diffusion, but one must know the proper technique for getting good soft-focus effects. Photo by Ray Atkeson, Portland, Ore.

cluding the special type of subject, there seems to be little doubt that the borate type of developer is the best of all in the class of balanced developers when gradation is accepted as the paramount factor.

Among the finegrain developers there are three types:

1. Those which depend upon the reducing power of paraphenylenediamine for the actual image formation.

2. Those which use paraphenylenediamine as an activator.

3. Those which follow the more conventional line, but which add to the developer one or more chemicals which react directly upon the silver (or the silver halide) grain to decrease its size physically through the action of chemical erosion.

The first type, those which use p-diamine as the actual developing agent and without alkali, hardly "bite" below the surface. As the result, a great increase in exposure is necessary—from three to five times normal. As the depth of the emulsion is not used, the possible number of gradations from minimum to maximum, regardless of contrast, is less than would be the case with a full-depth development. Fine grain is obtained by eliminating overlying strata, but tonal gradation is not of the best quality. In the second type of developer, the p-diamine starts the reduction of the image, which is then taken over by a conventional reducer such as metol or glycin, and the role of the p-diamine is more one of a mild accelerator than a reducer. The exposure is from two to four times normal. Grain pattern is not quite as fine as for the straight p-diamine, and gradation quality is improved.

The third type of finegrain developer does not require any increase in exposure time. Gradation is fully equal to the metaborate type inasmuch as the full depth of the emulsion may be utilized, and the grain pattern is conspicuously finer than in any other

full-depth development process. The favored method is reduction of grain size by the use of a thiocyanate.

However, there are pictures in every miniature salon made from negatives of the straight borate type, and even in sizes up to 11x14 these do not exhibit any out-of-control graininess except in individual cases here and there.

We have given formulas for types 2 and 3 in the preceding chapter. For those who wish to try the straight p-diamine, the following is recommended:

P-Diamine Finegrain Developer

Sodium sulfite, dry.....	2 ounces
P-diamine.....	180 grains
Benzoic acid.....	100 grains
Water to make.....	32 ounces

Expose 3 to 4 times normal. Used at 68°F, it is recommended that times from 20 to 40 minutes be used experimentally

This is the practical type of p-diamine developer. The ideal type is the same thing minus the benzoic acid. Try both to see just what the p-diamine factor is. Then when you realize that every improvement over this base is the improvement that goes with conventional reducing agents, you will realize the true position of p-diamine among developers.

Restrained Development

The process of developing, as we have seen, is rather involved, and is not strictly limited to the chemical reactions upon which it is based. There is the gradual release of alkali, the replenishing of the solution in contact with the film, and the removal of the bromide and other products from the film. The characteristic action of any developer must involve all these factors.

If we should spray enough developer upon the emulsion just to wet it, we would find the highlight development gradually slowing down because of the released bromide and exhaustion of the developer. On the contrary, shadows would release little bromide and would use little developer, so that we should have a development whose activity would be approximately inversely proportional to the density of the deposit developed. This would be a good idea if the original subject contained extreme highlights and very deep shadows—if it were, in short, a highly contrasty subject.

This kind of development is known in three varieties. In each the emulsion is first immersed in a developer of fairly high concentration. The first of these processes has been known ever since emulsions were developed. It used to be a part of the regular routine instruction to tell the beginner, "If you have an underexposure, develop it until the first trace of image is barely visible, then put it in a tray of water to develop. If development stops, put it back into the developer a few seconds and again transfer it to the water. Keep this up until the plate [*sic*] is developed, and you will have the best image you can hope for from underexposure." Yes, in those days it was always "plate" instead of "film."

This process we may describe as intermediate. The water serves to remove bromide and waste; development simply depends upon the exhaustion of developer in the highlights before that in the shadows. The negatives are normally clean, and shadow detail can be forced without clogging the highlights too much. When you learn the trick you can really do a lot with it.

Almost any developer will work, but excellent results have been obtained using a normal amidol developer. In this case the times of immersion in developer and water are:

Developer.....	45 seconds
Water.....	2½ minutes
Developer.....	1 minute
Water.....	2½ minutes
Developer.....	1½ minutes
Water.....	2½ minutes

The water bath is not agitated, as this would produce a redistribution of surface developer and also diffusion of the waste products.

A variation of the same method is now made the basis of commercial equipment and supplies. It is a very old process, also extending back to glass-plate days. The only difference is that the film is immersed in the developer from ½ to 1 minute, then squeegeed face down upon a glass plate and allowed to remain there for a given period of time.

The whole is immersed in water to prevent the film from pulling away from the glass plate at the edges as drying progresses.

An active, concentrated developer is recommended, such as the following borax formula; as a rule the developer has a greater proportion of alkali and less sulfite than the ordinary formula.

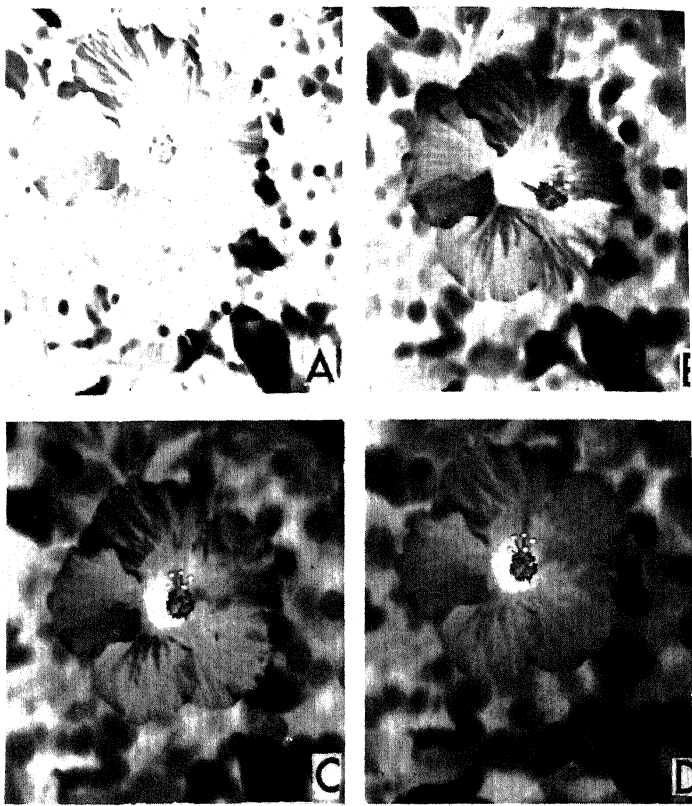
Concentrated Developer

Metal.....	½ ounce
Sodium sulfite, desiccated.....	1½ ounce
Sodium hydroxide.....	90 grains
Sodium carbonate.....	90 grains
Borax.....	1 oz. 25 gr.
Water to make.....	32 ounces

The distributors of the special equipment* recommend immersion for from 70 to 140 seconds, depend-

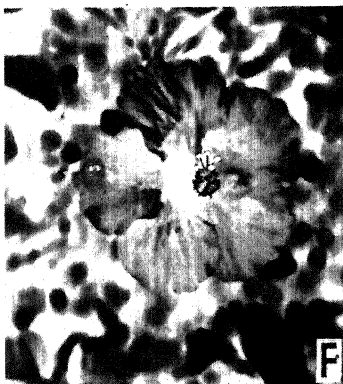
* P & H Process.

Fig. 55. Comparison of Negatives



This first series of four negatives was tank developed by time and temperature in a conventional borax developer according to recommendations by the film manufacturer. After correct exposure for the subject was determined, the four exposures were made: A, $\frac{1}{2}$ normal; B, normal; C, twice normal; D, four times normal.

Developed in Tank and in Air.



The four negatives E, F, G, and H were exposed the same as A, B, C, and D respectively, but allowed to stand for a half hour in cool air after five minutes in the developer. Notice in negative G where emulsion blistered and formed a hole. There is no evidence of the "leveling" effect claimed for this type of development.

ing upon contrast of the subject. The greater the contrast the shorter the immersion. The film is then pressed face down upon the special film ribbon supplied, and placed in water at 70° F. for 15 minutes. It is then fixed and washed in the usual manner.

The process is not successful with extremely low-potential finegrain developers, nor does it yield a finegrain image. But the chief objection is the fact that the shadows are built up almost as much by fog as by development, producing a veiled negative.

Almost identical in theory is the so-called air development. In this case the film is developed for a period of four or five minutes in a developer of low concentration, rinsed, and allowed to remain in air for one half to four hours, after which it is fixed. Obviously, the rinsing is to remove all surface developer which might produce streaking.

Striking claims have been made for such systems from time to time, including a claim that perfect development is obtained by using one time for films of all speeds, and that gross over- and underexposures are fully compensated for (see Fig. 55).

These systems all work, and some very striking results have been obtained. But, as with all other new developers, one may well ask if definite advantages are obtained which cannot be obtained even more satisfactorily by conventional methods. What do these systems really do? They permit the fullest possible development of the shadows without clogging highlights. In short, they are soft-working developers. Then why not use the following:

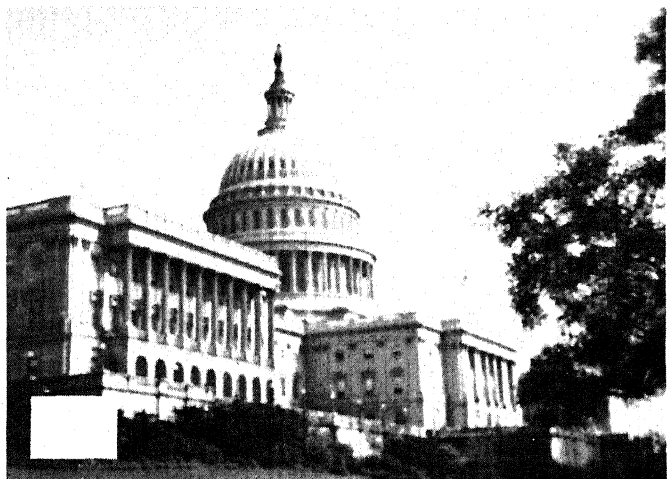
Soft-Working Metol Developer

Metol.....	225 grains
Sodium sulfite, desiccated.....	2 ounces
Sodium carbonate, monohydrated.....	2 oz. 60 gr.
Potassium bromide	24 grains
Water to make.....	32 ounces

It will give you a softer result than the trick methods of restraint. In fact, you'll probably find a bit of overexposure helps, because metal doesn't give very much density. However, the foregoing processes are of more theoretical than practical interest.

Ultra-Miniature Development.

There is one phase of specialized photography, however, which is definitely of interest, and this is the use of the ultra-miniature. For some strange reason



Unretouched enlargement from an ultra-miniature negative, the actual size of which is shown by the white block, lower left.

there is a belief that the size of a negative must influence its exposure and processing in some way. If you mark off a small area in any 35 mm film, say about $\frac{3}{8} \times \frac{1}{2}$ inch, and make a creditable enlargement

from that section up to about 5 x 7, you will have done exactly the same thing which the ultra-miniaturist does as routine!

As we have stressed so often, a great deal of the success in using the ultra-miniature camera lies in the special finegrained film used. For experimental purposes you can use Kodak Micro-File, Agfa Minipan, or Du Pont Microcopy film in the camera. When exposed, develop it in D-76, DK-20, or in some other finegrain developer **which will carry well down into the emulsion**. Limit development to the shortest time which will give you the desired contrast. Then you will find that you can enlarge up to 25 or 30 diameters without objectionable grain and without trouble.

The secret of using an ultra-miniature camera, such as the Minox, is exactly the same one we had to learn when the 35 mm cameras appeared; and that secret is wholly psychological. We dropped to the 35 mm and thought it marvelous that we could enlarge to 5 x 7 from those negatives. The 35 mm negative is about three times the size of the ultra-miniature in linear size. Therefore, using one film and one procedure, if we can go to 14 x 17 from 35 mm (and it isn't uncommon to see 30 x 40 blowups from 35 negatives!), it means that the same routine will give us enlargements about five inches wide from the Minox negative. And if we make a 30-inch print from 35 mm negative we can make a ten-inch print from the smaller negative. Add to this the possibility of at least doubling the size because of the ultra-finegrain film used and you can see why it is perfectly possible to make prints close to 16 x 20 from these small negatives without too much loss.

The technique of the ultra-miniature is the technique you are using right now. We expect any 35 mm camera to give us 11 x 14 and 14 x 17 salon prints, yet we don't as a rule ask the ultra for anything



Original 8x10 print enlarged from an ultra-miniature negative processed in a finegrain developer by a commercial finisher.

above 5 x 7. More often we use it to produce album prints about 3 x 5 inches, and for that purpose the tiny camera delivers the goods just about as well as the average postcard-size camera!

Watch temperature closely. Keep all solutions at the same temperature. The Minox tank requires only one ounce of developer, so this is easy. Use a mild hardener or use a hardener-hypo bath. Immediately after washing, remove all surplus water with Textilex paper, and you'll go up as far as you like. I had no trouble in enlarging to 20 diameters on glossy paper with a Minox negative which had been developed in DK-20, and in going to 40 diameters from the same negative on matte paper, with entirely satisfactory results. The latter showed the start of break-down, but it was still sharper than many salon prints which are hung.

With a super-finegrain developer there is little doubt that this film will stand upwards of 60 to 70 diameters without more than slight loss, and certainly up to 25 or 30 with excellent results.

This has been brought into the discussion simply to emphasize the fact that special techniques, especially when they are concerned with small negative sizes, are about eighty per cent psychological and twenty per cent technical.

Physical Development.

There is one kind of special development which produces good quality, good grain structure which is exceptionally fine and independent of the grain pattern of the original emulsion, and which gives a proportionate density effect throughout the tonal range. All in all, it is a super-super developer. The only catch is that it demands careful workmanship, the last word in chemical cleanliness . . . and then sometimes it simply

doesn't work! This is physical development.

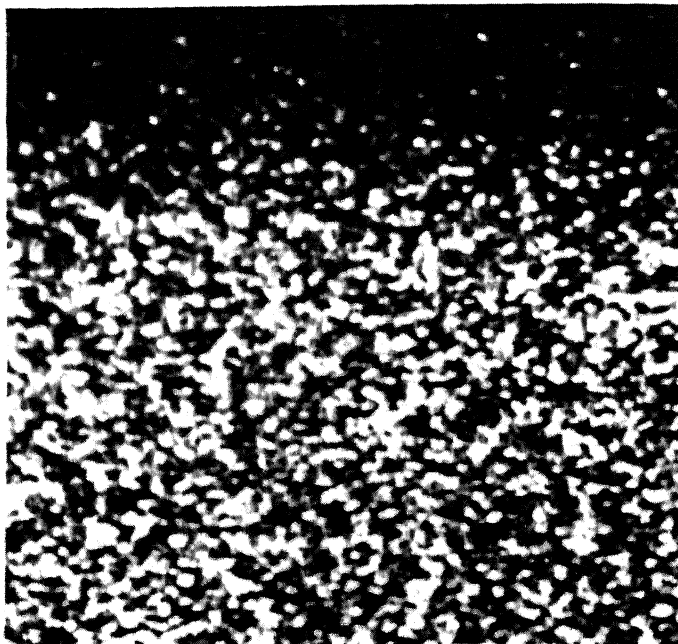
Now let us consider again the step-by-step routine of ordinary development, which we shall call "chemical" to distinguish it from "physical." The developing solution enters the emulsion which has been exposed to light. Silver bromide is dissolved, the bromine thrown out, and the silver redeposited in metallic form. The silver in the image comes from the silver bromide in the emulsion, and the quantity of silver in the image is that quantity which was in the exposed portions of the emulsion. As slightly exposed silver grains are harder to develop, the low limit is pushed up to form a curve (the toe of the characteristic curve, underexposure).

In physical development there is a slight chemical development at the start, but the principal action of the physical developer is to **plate silver upon the film**, using the image centers as centers of deposition. In short, the developing solution contains silver, and this silver is deposited upon the early silver image. The contrast is that of the original subject, because the image is built up uniformly and is not affected by the chemical factors which alter chemical development, such as the accumulation of free bromine.

Straight physical development was not unlike mirror plating. The plate (and it had to be a plate) was placed in the silver solution, horizontally and face up. The deposition was in part electrolytic and in part gravitational, it would seem, for success could not be obtained with the plate in any other position. We have to thank Dr. Allan F. Odell for working out a practical solution to this problem. Using the Odell method it is possible to obtain perfect negatives from physical development regardless of the position of the film in the developing solution.

Physical development was discovered in 1858 by a photographer named Young. It was advocated

occasionally thereafter, but the tremendous exposure and long development were against it. In the decade preceding 1925, Lumiere and Lüppo-Cramer, well-known photographic researchers, made valuable addi-



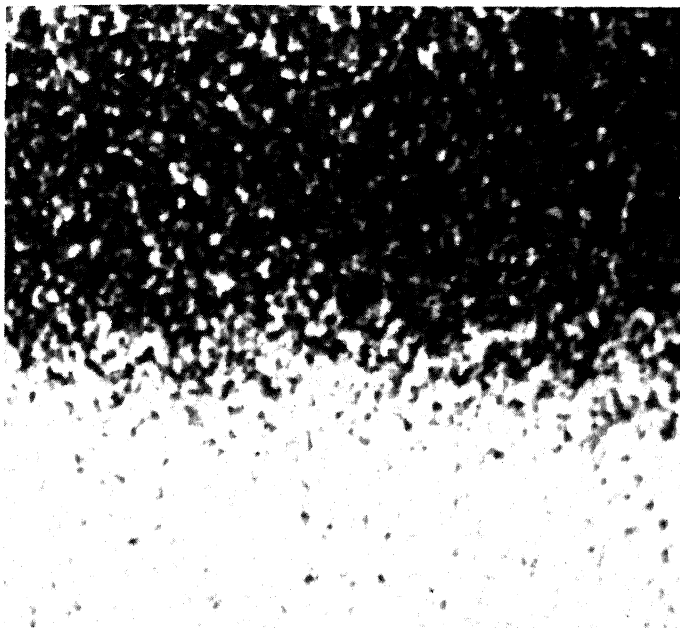
Photomicrograph of negative developed in p-diamine made at low power to avoid "optical sectioning" and show the true pattern.

tions, and finally in 1933 Odell published his perfected process, which does not involve any appreciable increase in exposure.

The tanks used for physical development should be made of glass, bakelite, stainless steel, chromium,

or other material which may be cleaned thoroughly and which is chemically inert. Before use, tanks should be washed with dilute nitric acid and rinsed with distilled water.

In this process it is essential that all water used



Physically developed negative appears more grainy in the photomicrograph, but the projected image proves the reverse is true.

be distilled. No matter how pure the tap water is, it should not be used. The process consists in treating the film with a solution known as a "forebath," after which it is immersed in the actual developing solution. Following development, the film is fixed and washed in the usual manner.

It is a curious fact that films can be fixed out and then, after fixing, the image may be developed upon the fixed-out emulsion. However, this process is practical only with films which have been specially exposed, as an exposure of from ten to twenty times normal is required if the development is to be successful. We shall first consider the conventional before-fixing development.

The forebath is made up as follows:

Forebath

Potassium iodide.....	80 grains
Sodium sulfite, desiccated.....	195 grains
Water to make.....	16 ounces

This forebath is filtered before use, and if used more than once it must be filtered before each use. It is also advisable to filter it after use. Store it in a brown or black bottle, and do not use more than five times. The time in the forebath is about four minutes at 68° F.

The developer is prepared immediately before use from a stock solution. This is:

Physical Developer—Stock Solution

Sodium sulfite, desiccated.....	1 ounce
Silver nitrate.....	120 grains
Hypo crystals.....	2¾ ounces
Water to make.....	16 ounces

Dissolve the sulfite and silver nitrate in separate portions of the water, pour the silver nitrate into the sulfite, then add the hypo. Filter after mixing, and keep in a bottle which is completely wrapped in black

paper. The working solution is made as follows:

Stock solution..	3 1/4 ounces
Water to make	16 ounces

Dissolve 12 grains of amidol in this working solution, and filter before use. Developing time is 30 minutes at 65° F. with **constant agitation**. Use the working solution once only. After development, rinse the film and wipe surface with wet cotton. Rinse again and place it in hardening hypo. These steps are carried out in the darkroom. From this point the procedure is normal.

For fixing which is to be followed by development, give an exposure at least ten times normal, then fix in a plain hypo bath to which has been added about one per cent of strong ammonia (2 1/2 drams to 32 ounces). Do not fix for more than five minutes, and alkalyze the wash water with a few drops of ammonia. The formula for the developer* is as follows:

Developer to Follow Fixing

Solution A.

Sodium sulfite..	3 oz. 270 gr.
Silver nitrate, 10 per cent sol	1 1/2 ounce
Water to make..	20 ounces

Solution B.

Sodium sulfite..	175 grains
Paraphenylenediamine base..	175 grains
Water to make..	20 ounces

Mix in equal parts and develop in full light. As soon as the precipitate begins to drop out of suspension—that is, when the cloudiness in the solution begins to settle downward upon the reel—throw away

* From "Photographic Facts and Formulas," by E. J. Wall & Franklin I. Jordan, 1940.

the developer and fill the tank with fresh solution. In any case renew the solution every hour. Development may be carried to any degree by extending the process over several hours. It may be stopped midway and later finished by physical intensification (to be discussed in Chapter VII).

It has been intimated that physical development is unreliable and not uniform. This is not strictly true. The trouble lies in the fact that the average amateur has not been thoroughly trained in chemical cleanliness, and he simply does not understand the extent to which this must be carried.

If the stated precautions are taken, if the tank is thoroughly cleaned and rinsed with dilute nitric acid, if all glassware is similarly cleaned, if the solutions are kept in dark bottles and filtered before use, and if minor apparatus such as funnels, stirring rods, and so forth are given the same treatment as the tank, then there will be little probability of difficulty. The strange pranks of physical development come to those amateurs who have been accustomed to chemical developing, and who cannot understand why a tank which has been scrubbed thoroughly with hot water and a cleansing soap is not chemically clean. Perhaps we should adopt the word "uncontaminated" in place of "clean."

Because physical development is in one sense a plating process, it is possible to carry it out as long as there is anything to form the base. Thus, any negative (regardless of the type of original development) may be intensified by this process. The half-developed negative may be completed at any reasonable later date; in fact, any silver image may be strengthened by its use.

The limit of resolving power in physically developed negatives is very close to the limit of the emulsion itself, as a factor apart from graininess.

Steel engravings are copied at $\frac{1}{10}$ to $\frac{1}{20}$ natural size and later projection proves the individual lines to have been retained in the small negative. It is a wonder process, but obviously not adapted to the careless darkroom worker.

Three-Color Separation Negatives.

There is another special technique which the more ambitious amateur will want to understand. This is the control of the three-color separation negative. The problem is that of obtaining negatives of the same gamma, although the blue filter and the red filter are known to reduce and increase contrast respectively. It is not at all uncommon for the three negatives to be made upon a color-blind, a high green-sensitive ortho, and a panchromatic emulsion respectively (as with Defender Tri-Pac film); but it is also common practice to make all three with panchromatic emulsions, using standard tricolor filters.

The normal growth of the image in any negative is known to progress from low gamma to high, and the usual method for developing these negatives is simply to develop the blue-filtered negative for a longer period of time. This produces a workable result in most cases, but there is always a certain absence of identity in the tonal scales. Usually the blue-filtered negative is developed to bring the middle tones to a balance with the other negatives, leaving the highlights and shadows to fall where they may. The exposure given must be corrected to correspond to the development given.

When the highlights are too dense and the shadows too weak in the same negative it indicates that under-exposure has been followed by overdevelopment. In remaking this negative the exposure must be increased to bring it up to normal for shadow detail. Then if

development is limited to the normal time, both highlights and shadows will be printable. However, when the case is an extreme one, it indicates an excessive amount of contrast in the original subject. In this instance you can do either one of two things—and as both are identical in point of manipulation, it makes no difference which name you give it—you can “expose for the shadows,” or you can deliberately give more than the normal exposure for the overall subject. This is followed by shortened development. The increase in exposure will provide the desired density in the overexposed middle tones and lower tones, while the shortened developing time will terminate development of the image before the highlights have time to gain too much density.

This involves a conception of exposure which some of us have not learned. In any negative the deep shadows are underexposed and the highlights are overexposed. The single exception is that of a very flat subject, all of which can be recorded upon the middle or “straight line” portion of the emulsion’s characteristic curve, as will be explained in the chapter dealing with sensitometry. Thus, instead of having highlights which are overexposed, we have highlights which are somewhat more exposed than normal, but whose final density factor can be controlled by the time of development. The pivotal factor is to maintain **normal density in the middle tones**, so that any negative which is to be given less than normal development must be given a compensating longer exposure to hold the middle tone density at the normal degree.

If this principle is followed, it will be possible to produce a series of negatives with practically identical middle tones, yet in which the extremes of shadows and highlights range from the minima of almost identical density with the middle tones up to clear film base and complete opacity, respectively, as maxima.

Thus it will be seen that the filter factor alone is not a sufficient guide for determining the exposure. The factor must include the exposure correction which will permit the right degree of development to bring the density scale into the desired range, as well as correcting for the average normal exposure.

It is sometime advantageous to make a separate developer for the blue-filtered negative—one which will build it up to a higher gamma in the same time required for the other negatives. A contrast developer may be used, or the regular formula may be varied to produce the desired results.

We know that the addition of more alkali will tend toward greater contrast, and so will the increase of hydroquinone; but these simple increases are not enough. When the alkali in any developer is increased, there must also be an increase in sulfite, and when the developer is thus energized there is usually a need for some increase in bromide. Thus, if a normal developer contains eight times as much hydroquinone as metol, it may be made softer by using equal amounts of both agents, with a reduction of, say, twenty-five per cent in both sulfite and carbonate, or it may be made harder by increasing the hydroquinone to as much as fifteen or twenty times the metol and increasing the sulfite and carbonate by fifty per cent. When making the softer-working developer, the metol may be increased up to double the normal amount (and hydroquinone of equal quantity used), but in making harder developer the normal metol content is not usually decreased.

This is a highly generalized statement, but on the whole most control developers will be found to vary from these basic principles only a slight amount.

In all color-separation development, the actual result of development must be checked by measurement. Visual inspection is not enough. Therefore, if you

expect to do much of this kind of work, you will find it necessary to make or obtain some kind of densitometer (to be discussed in Chapter IX).

For example, let us use the two sets of three-color materials produced by Defender—the Tri-Pac, which is a set of three films assembled into one unit and designed to be used in an ordinary camera, and the 3-color Negative Assembly designed for use in one-shot cameras. For the Tri-Pac, the following developer is recommended:

Defender 6-D Finegrain Developer

Metol	29 grains
Sodium sulfite, desiccated	3¼ ounces
Hydroquinone	75 grains
Borax	29 grains
Water to make	32 ounces

The balance of these Tri-Pac negatives is affected by the type of light which has been used. In the case of daylight, it is assumed that the exposure has been made with the Wratten 86B filter, as recommended. The times in minutes for development at 70° F., as given by Defender, will then be:

Light	Front film	Center film	Rear film
Daylight	9½	9	10½
Photoflash	9½	9	11½
Photoflood	10	9	10
Mazda	11	9	9½

The Defender 3-Color Negative Assembly is used in one-shot cameras as a bipack (Dupac), and a single film (Blue Record). Developer 4-D is recommended.

Defender 4-D Developer

Metol	37 grains
Sodium sulfite, desiccated.	2½ ounces
Hydroquinone.	45 grains
Borax.	75 grains
Water to make.	32 ounces

The developing table provides three times of development, which will give gammas of approximately 0.7, 0.8, and 0.9 respectively.

Gamma	Blue record	Green record	Red record	
	Front bipack	Rear bipack	X	A
0.7	11½	5½	6	6
0.8	15½	8	7¾	7½
0.9	19	9½	8¾	9

In the red record there is a choice between two panchromatic emulsions, the XF Pan indicated by "X" and Arrow Pan indicated by "A."

The development of color-separation negatives is quite an art, and upon it hinges most of the success in color photography. It is also fascinating, and once you have mastered it you have nothing to fear.

Development at High Temperatures.

There are also special developing techniques necessitated by location. Tropical development by the use of a hardener in the developer has been discussed, but there are other methods. Development at high temperatures may be performed by:

1. Preventing swelling of the gelatin (as with sulfate).
2. By using a developer with low alkaline reaction (as a standard amidol developer).
3. By making the time as short as possible so

that the gelatin does not have time to swell.

As we are already familiar with 1 and 2, we shall consider the third method of high temperature development. The method most often favored is the two-bath type which is familiar to most amateurs as "divided development." However there is one which is a typical "shot-gun" developer of extremely rapid action. This formula was given to me by a press photographer who did not know its origin. I have not tried it out, but here is the formula for what it is worth.

Rapid Action Developer

Metol	½ ounce
Sodium sulfite, desiccated	3 ounces
Hydroquinone	1 ounce
Sodium hydroxide	1 ounce
Formalin (40% sol.)	1 ½ fl. oz.
Water to make	32 ounces

Wet the negative thoroughly with plain water. Immerse quickly in the developer, agitate for fifteen seconds, remove and drain not more than three seconds, and place in chrome alum—acid short-stop for one and one-half minutes, fix in hardening hypo, and continue normally.

The Eastman SD-6 formula is a rapid divided developer for press work.

Eastman Rapid Two-Bath Developer—SD-6

First Bath

Metol	44 grains
Sodium sulfite, desiccated	365 grains
Hydroquinone	88 grains
Sodium sulfate, desiccated	3 oz. 145 gr.
Sodium carbonate, desiccated	290 grains
Water to make	32 ounces

Second Bath

Solution A.

Phenosafranine (1:1000 sol.)	5 fl. drams
Sodium sulfite, desiccated	1 oz. 290 gr.
Potassium bromide	30 grains
Water to make	32 ounces

Solution B.

Formalin (37% sol.)	6½ fl. oz.
Water to make	32 ounces

To make second bath, take equal parts of A and B

Develop in the first bath for one minute at 65° F.; transfer to the second bath without rinsing, and develop for one minute. Short-stop and fix.

Such formulas would appear to be just what should be avoided in high temperatures, but the brief period of immersion, together with the hardeners in the solutions, prevents any excessive swelling of the gelatin. As such swelling must precede destruction of the gelatin, the processes are safe at higher than normal temperatures (see Fig. 56).

It is obvious, of course, that the same procedure will enable a negative to be produced in a very brief time. If the fixing is stopped as soon as the negative is cleared, then washed for not more than five minutes, blotted with Textilex and alcohol dried, it will be possible to make a print within fifteen to twenty minutes after the first immersion in developer. However, no great quality is to be expected in the negative, nor will it be permanent unless it is thoroughly rewashed after the printing.

Printing from Wet Negatives.

The negative does not have to be dried to be used for projection, nor for contact printing either. If the wet negative is to be used for contact printing,



Fig. 56. Print from a negative developed in a rapid two-bath developer; temperature in darkroom and of solutions was 86° F.

it is rinsed in a bath containing about five per cent glycerin, then laid upon the glass of the printer in a small pool of glycerin. Another small pool of glycerin is poured upon the face of the negative, and a very thin sheet of celluloid (not cellophane), is carefully laid over the film. It is pressed flat and all air bubbles worked out. It is then ready for printing

in the way any negative is printed. After printing, the glass of the printer may be cleaned with water, and the glycerin removed from the negative by thorough washing.

Enlarging is done in a similar way except that the negative is sandwiched between two sheets of glass, with glycerin on both sides. Be sure not to heat the negative too much in the process, and do not have enough glycerin to run out around the edges of the glass and drip down into the enlarger.

Glycerin is used because it mixes perfectly with water with no visible reaction; it is colorless and clear; it resists drying by evaporation for long periods; and it serves to make a thorough contact between the two glass sheets and the film so that any irregularities in the film will not affect the print.

Other Uses for Glycerin.

This brings up the subject of other uses for glycerin, but it will be necessary to give a few moments to a discussion of the importance of refractive index—the angle of deviation of a light ray when passing obliquely from one medium to another.

Glycerin, plastic solutions, and Canada balsam are used to cement dry negatives between glass sheets before enlarging, with the purpose of eliminating surface scratches and other mechanical defects, particularly in the case of old negatives which have been kept in rolls or in direct contact with other negatives.

You have no doubt noticed that when a spoon is placed in a glass of water, or a stirring rod is placed in a mixing graduate, there appears to be a break in the rod at the surface of the water. From some directions the rod simply appears bent, but from others there is a complete visual separation of the upper and lower portions of the rod. This is caused by the

refractive index of the water; that is, water will bend a ray of light which enters it obliquely from air.

If you place a hollow glass tube in water, you can see the bore plainly, outlined by dark lines and with a separate reflection pattern. However, if you place the tube in glycerin or a balsam solution, it appears to be a solid rod.

We may take the refractive index of glass as being somewhere near 1.5, as it varies with the different kinds of glass. Water, we may assume, has an index of about 1.33, while glycerin has an index of about 1.48. There is a considerable difference between the indices of glass and water (about 0.17) while the difference between the indices of glass and glycerin is only 0.03 or 0.04. This means that a light ray will pass into glycerin, then into glass, then into glycerin, then into glass, then into glycerin with very little disturbance. If the glycerin is replaced by water there will be considerable refraction at each boundary. When there is very slight refraction the light passes as it would through a homogeneous substance, while when greater refraction occurs the divisions between the two substances are made quite visible.

Now assume that you have a film which is made of celluloid and coated with gelatin. Gelatin has a refractive index of about 1.51, near that of the lighter forms of glass, while the refractive index of celluloid is about 1.47 to 1.5. If there are scratches upon either surface they will appear as dark or black lines, because of the difference in refraction at the scratch. As the sides of the scratch channel are at an angle to the film surface, there will be such a difference in degree of refraction, and this of course will cause a black line to appear along the scratch. These lines appear as white lines on the enlargement just as definitely as though they were lines produced by some opaque pigment on the film.

If the negative is placed in an enlarger these scratches will appear whether the film is in an open holder or between glass plates, because no matter how tightly the film is compressed between the plates there is still a layer of air sufficient to produce the effect. The single exception is that of optical con-

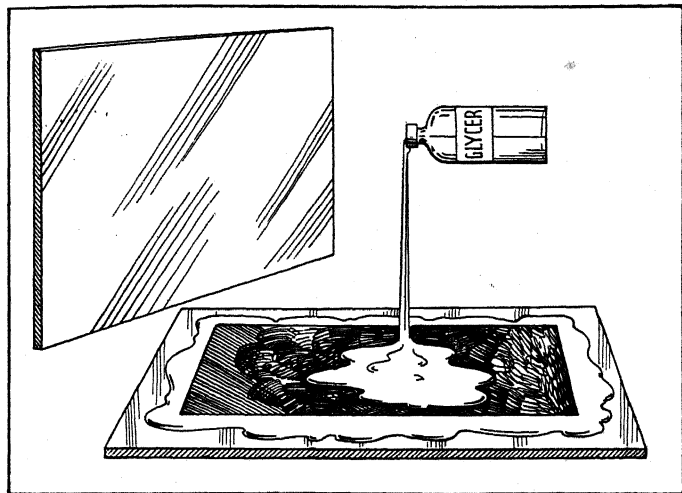


Fig. 57. Scratched negative will produce a good print if covered on both sides with glycerin and sandwiched between glass.

tact between celluloid and glass, which results in the appearance of the areas we commonly call **Newton's Rings**.

However, if the negative is covered with glycerin and then placed between the glass plates (see Fig. 57), and if the glycerin is thoroughly worked into the film to eliminate air bubbles, it will form an optical bond between the film and the glass, and you will have what amounts to a solid slab of glass with the silver

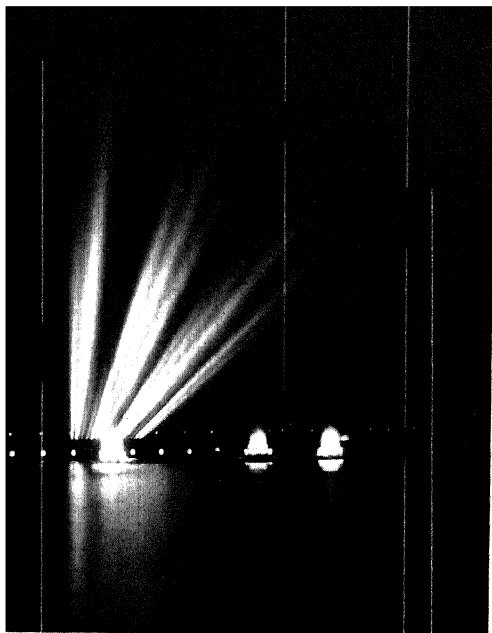


Fig. 58. Print from a negative which shows scratches caused by film rubbing against pressure plate when advanced in camera.

image suspended in its interior. As far as optical results are concerned, gelatin, celluloid, and glycerin all disappear, and mechanical defects in celluloid or gelatin must also disappear (see Figs. 58-59).

As a rule, glycerin is used for making temporary mounts of this kind, but if the film is of considerable value and a number of prints are to be made from it from time to time, a permanent mount can be made by using a solution of Canada balsam in xylene in place of the glycerin. This balsam has a slightly higher refractive index than the glycerin, but it hardens by the evaporation of the xylene and makes a solid, one-piece mount. This is the material commonly used to cement elements in making a lens, so its suitability and durability can be appreciated.

Permanent mounts of this kind should be stored

Fig. 59. Scratches do not show in print from the same negative when covered with glycerin and placed in a glass "sandwich" (Fig.57).



flat for about six weeks to two months after they are made up; then they can be stored in any convenient position. If the negatives are 35 mm, the perforations can be trimmed off and the negative mounted upon a standard microscope slide.

The Reversal Process.

There are times when a direct positive is desired without first making a negative. This is usually performed by the reversal process. (See reference to direct positives on solarized films, page 326.) The reversal process was first popularized in connection with making natural color transparencies with screen (mosaic) plates such as Lumiere Autochrome and Dufaycolor.

The general theory is this: After exposure, the negative is developed in the usual way. When this has been done there is still a considerable amount of sensitive silver salt remaining in the emulsion, and in any given area of the emulsion the amount of sensitive material left is inversely proportional to the amount of metallic silver which has been deposited.

After development is complete there are two possible methods, both of which are used to accomplish the same purpose—that is, to make an exposure which will produce a positive image.

In the first method the developed negative is thoroughly rinsed in water, and is then exposed (image side toward the light) to a light of sufficient intensity to expose the sensitive material beneath the developed image. In this step the exposure is made **through** the negative image, just as in ordinary printing.

In the second method the negative is placed in a bath which will remove all the silver which forms the image but without disturbing the sensitive material which remains in the emulsion. After this bleaching, the emulsion is exposed to light so that the remaining sensitive material is exposed; it is then developed to produce a positive image (see Fig. 60).

Following the first method, the image is bleached out after exposure and the second or positive image is developed. When this method is used, the second exposure is a measured, controlled exposure. By using such an exposure there is a printing control possible, just as though you were printing in a conventional manner. After exposure, the bleaching and second development are all carried out in the dark or under a dim green safelight (presuming pan film is used). After development of the positive image the film is fixed in the usual hypo and from that point on procedure is normal.

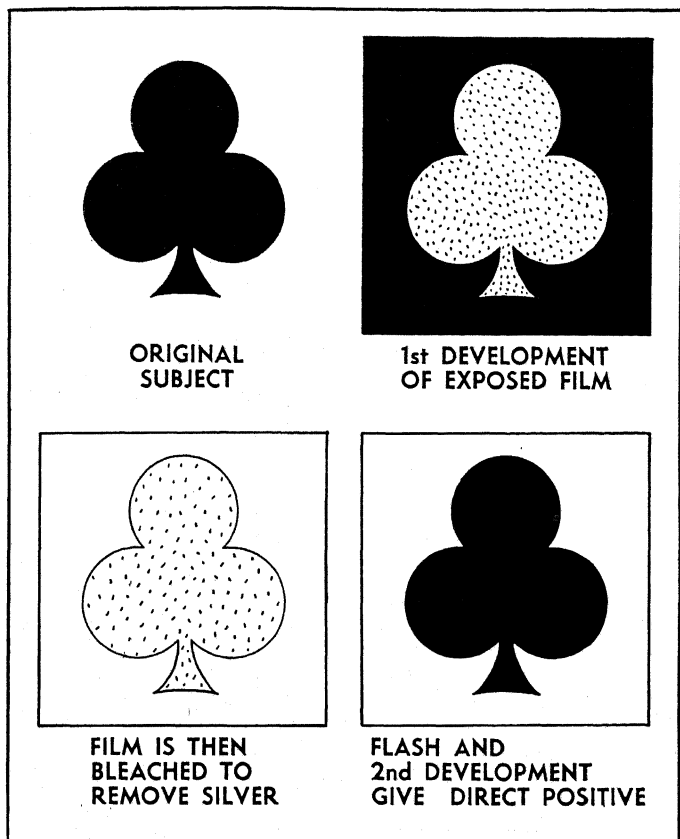


Fig. 60. Sketch showing principal steps in the reversal process. Original is photographed and negative developed. Silver negative image is bleached away, and the film exposed to white light. Second development then produces the positive image.

In the second method the developed negative is placed in the bleaching bath, and after a moment or so the ordinary white light is turned on and all subsequent steps performed in full light. It will be seen, therefore, that the second process utilizes all the remainder of the emulsion, thus making the positive quality dependent upon the original exposure and development. The first process may or may not use up all the sensitive residue, and to this extent provides some control where the original is too thin. With too thick a negative image both methods would use all the residue and perhaps necessitate intensification.

The second process is more commonly used because it is so much more convenient to work under an ordinary white light. The emulsion used should be somewhat thin and, if possible, a single-coated emulsion. Double-coated emulsions—that is, where both a fast and a slow emulsion are coated on the same base to extend the film latitude—do not give very good results with reversal. Slow, rather contrasty emulsions work best, and the straight, normal positive emulsion is one of the easiest of all to reverse. If a pan emulsion is desired, it is suggested that Micro-File, Microcopy, or other slow, contrasty pan film be used.

A number of reversal formulas have been suggested, and most of them work. Perhaps the Dufay-color procedure will prove as satisfactory as any. It will be noticed that thiocyanate is used in the first developer. This is not only for grain size control, but it also facilitates a rapid invasion of developer and permits a full development with the least amount of fog. The developer should be strong, have a low concentration of sulfite which might otherwise promote a “physical” development action, and it must be fresh.

Dufaycolor First Developer

Metol.....	15 grains
Sodium sulfite, desiccated.....	1 3/4 ounces
Hydroquinone.....	117 grains
Sodium carbonate, desiccated.....	1 oz. 75 gr.
Potassium bromide.....	75 grains
Potassium thiocyanate.....	132 grains
Water to make.....	32 ounces

The emulsions commonly used for reversal will develop in from two to four minutes in this solution, at 65° to 68° F. After developing, the film is washed in running water for one minute (actually sixty seconds by a timer, not some period at which you may guess). It is then placed in the following bleaching bath:

Permanganate Bleaching Bath

Potassium permanganate.....	45 grains
Commercial sulfuric acid.....	2 1/2 fl. drams
Water to make.....	32 ounces

Remember the warning! Pour acid into water slowly, and never pour water into acid. Stir constantly while mixing.

Keep film in motion in bleaching bath. Bleach until all the black color of the negative image has disappeared. Usually the image will be plainly visible and of tawny orange color; the color is often masked by the purple color of the permanganate solution. The white working light is turned on after about two minutes bleaching. Another two minutes, or four minutes in all, will usually complete the bleaching, but be sure that there is none of the black image remaining.

Wash the film for two full minutes in running water. then place it in:

Clearing Bath

Sodium bisulfite.....	3/4 ounce
Water to make.....	32 ounces

In making this solution, potassium metabisulfite can be substituted for the sodium bisulfite in equal quantity, if desired. The film remains in this solution until the colored stain of the permanganate has all been removed. This usually requires about two minutes. After the film is cleared the image will have more or less of a straw or cream color. It is then washed for three minutes to remove the bisulfite.

At this time the film is ready for the second exposure. The fact that the emulsion is wet and that it has been through quite a procedure renders it far less sensitive than originally, and simply working under white light does not provide sufficient exposure, so it is given from one-half to one minute exposure at a distance of about eighteen inches from a No. 1 Photoflood lamp. It is then ready for development a second time. Any good developer used for positive work, usually a metol-hydroquinone developer, will serve. In the absence of any favorite formula try the following:

Second Developer

Metol.....	30 grains
Sodium sulfite, desiccated.....	2 1/2 ounces
Hydroquinone.....	135 grains
Sodium carbonate, desiccated.....	1 3/4 ounces
Water to make.....	32 ounces

The developing time is about four minutes at 65-68° F. The first developer may be used for the second development if desired, but when a bath has

been used for the second development it can no longer be used for any further first development.

After development, the film is rinsed and fixed for about three or four minutes in any standard hypo. It is then washed and dried in the usual manner.

The above procedure may be used for developing direct color plates and films of the mosaic screen variety, but it is not suitable for Kodachrome, which is based upon an entirely different principle.

Solarization.

Photography is subject, probably more than any other field, to rediscovery repeatedly repeated. Every once in awhile the journals will carry a report of a "discovery" which was common knowledge a decade ago, and in many cases the discovery hailed as great today was simply an error then. So we have photography filled with the "Jones Effect," the "Smith Reaction," the "Brown Process," and all of them were part and parcel of the essential knowledge of the photographer who had to work out his own problems before the age of mechanization.

Instructions to the amateur using the newly invented gelatino-bromide dry plates, published less than a century ago, had this bit of information to offer: "Take the utmost precaution against the entry into your working room of the tiniest beam of light from any source. It is certain to play havoc with your work and will often produce a peculiar result which is half negative and half positive; and being constituted of both remains neither the one nor the other, and for that reason becomes entirely worthless."

Well! Well! And who would have thought that decades later Man Ray would set the photographic world agog with that same "neither the one nor the other and so worthless" effect? And who would

imagine that someone who picked it out and emphasized the fact would be credited with the discovery and it would be known as the **Sabatier effect**? Well, let the boys have the honor. It does take time and effort to work out the specific data which underlie many photographic phenomena; but as for discovery . . . just remember that Leif Ericsson did really discover America, and he did colonize it; remember that Columbus never saw nor set foot upon the American continent. . . . and again remember that Ericsson was possibly number eleven or thirty-seven in the true list of the discoverers of America, if we only knew the truth. And so much for discovery. You can accept it as a more than 50-50 gamble that discovery is usually rediscovery, and we never know to what degree.

There are a lot of interesting things to be done in exposure, many of them depending upon **solarization**. First let's get the correct definition of that word. Although solarization is loosely applied to the semi-reversal which mixes negative and positive, it really means an exposure continued for such a length of time that the original latent image is destroyed. The familiar example is that of a landscape which includes the sun. More often than not the negative image of the disk will have no deposit, and the print will show a **black sun**.

Closely allied to solarization are the various effects obtained by any great degree of overexposure. For example, there is the effect which is sometimes called the **Albert effect**. A great overexposure is given in the camera, say from one hundred to five hundred times normal. This far exceeds all limits of exposure for normal after-treatment, and brings the sensitive material to the verge of spontaneous breakdown—that is, darkening without process of development. The film is then oxidized with potassium permanga-



Photo by L. Marcellus

Solarization or partial reversal, once considered a "worthless" process, has been employed in recent years to produce photographs which are strikingly different from what we are accustomed to seeing. Opinions differ as regards the artistic merits of this technique, yet there is no denying that some very unusual, and interesting effects can be obtained by the skilled worker.

nate, which bleaches the negative image just as it does the developed image in the reversal process, after which exposure to light followed by development produces a positive, just as in conventional reversal.

Still another process is that in which the film is given a heavy, uniform flash exposure to white light, not in a camera. This would, by ordinary development, produce a uniform black negative. However, before development it is printed under a positive, a good hot infrared (heat) lamp being used for the purpose. This lamp is filtered so that only the infrared (which may be mixed with a small amount of visible red without harm) reaches the film. The latent image is destroyed by the infrared, and as this is modulated by the positive transparency, development will produce a positive image.

One of the few practical results which have been accomplished is that of chemically "flashing" emulsions during manufacture, so that ordinary exposure and development will produce a positive image rather than a negative one. This is ordinarily used as a printing medium, rather than in the camera. The so-called **direct positive films** are of this type.

Limited Water Supply.

To get back to sound procedure, there is the problem of the photographer who has a limited amount of water available, yet who must process his films on the spot. Such a condition certainly indicates the traveler or the explorer, for where there is a fixed human habitation an acute shortage of water is usually an accidental occurrence or a condition which is present only during a part of the year. In the case of the traveler, the first thing to do is to stock up on the necessary chemicals in the form of pre-

measured, compressed tablets. The Burroughs-Wellcome Tabloid products have saved too many negatives even to be numbered. While somewhat more costly, they are of consistent quality, and for many years I developed a large number of my negatives in a Tabloid developer. You can carry a complete supply of photochemicals in your coat pockets in this compressed form.

However, that is beside the point, except that small amounts of water may be used in making up correspondingly small amounts of solutions. When the film has been developed it is fixed in a hardening-hypo. When fixing is complete the film (or tank reel) is suspended and allowed to drip while the tray (or tank) is wiped thoroughly with blotter, cotton, or even a clean rag. The tray is half filled with water and the film placed in it for ten minutes. The process of draining and wiping out is repeated. The film is then soaked for another ten minutes. Repeat this until the film has had six periods of immersion. It will then keep for several months, after which it may be thoroughly washed; but for permanence without further treatment, ten to twelve changes of water are advisable. If the film is blotted in Textilex between changes, the process will be even more effective, so that a film can be well washed in ten pints of water, assuming that a sixteen-ounce tank has been used.

This does not agree with the "third equilibrium" theory which has been given earlier, but under actual working conditions—some carelessness, some "carry-over," and the always human temptation to cut things a bit short to save time—the above process will just about parallel the laboratory-controlled "third equilibrium."

When the "water shortage" means that the photographer is at sea and fresh water is limited, he need have no fear. Ordinary washing may be done in sea

water, and in that case a final double change of fresh water will prove entirely satisfactory.

Dye Toning.

And finally, for those finegrain addicts who want to take a little trouble, we offer the dye-toning process. In this process the silver grains are replaced by dyed grains, and as there is a certain amount of dye diffusion, the sharp outlines of grains are masked, and the image takes on a more uniform tone. This, however, does not produce any diffusion of the image greater than that obtained by the original negative, as the diffusion is limited to a fraction of the original grain size. Red or orange dyes appear to give more satisfactory results than the blues or greens, no doubt because of their non-actinic character.

One of the advantages of dye toning is that the process, if continued, will produce some degree of intensification which does not take place when the dyeing time is more limited. Thus it offers a certain degree of control which may be of help in saving some thin negatives. However, like other intensifiers, there is little hope for the thin negative where there is no original deposit upon which to build the dyed image. Also, and contrary to statements which have been made from time to time, this process does not provide a truly grainless image. Its sole advantage lies in the fact that diffusion introduced is of such minute absolute size that it does not in the least affect definition, and thereby does eliminate a **certain degree** of graininess. At any rate, it is well worth experimentation.

The original negative should be clean and free from fog. A negative which has been desensitized before development is an excellent base for this process. The first step is to "mordant" the image. This

process changes the silver of the image to silver ferrocyanide. The film must be entirely free from hypo before it is mordanted.

Mordanting Bath

Uranyl nitrate.	25 grains
Oxalic acid.....	12 grains
Potassium ferricyanide....	12 grains
Water to make.....	32 ounces

The chemicals are mixed in separate small portions of water; pour the oxalic solution into the nitrate solution, and then add the ferricyanide. Otherwise a precipitate will form which cannot ordinarily be dissolved. The solution should be pale yellow and water clear. It is light-sensitive, and should be stored in a bottle covered with black paper.

The film is left in this bath until it becomes a deep chocolate color. This step is important; almost all beginners over-mordant. A comparison negative should be kept at hand, for the only difference is that the average negative has a cold black color while the mordanted image has a warm black color. Do not carry mordanting to the extent where the image has a definite sepia color.

The actual time of mordanting in a fresh bath is usually about two minutes, and the mordant should not be used for more than about seventy-five square inches per quart, or fifty feet of 35 mm film.

After the mordanting, which may be carried out at a temperature as high as 75° F. but no higher, the film is washed until all yellow color is removed. This usually takes ten or fifteen minutes, but in no case wash for more than twenty minutes, or the mordant will start to wash out and inferior tones will result.

When the mordanted film has been washed free

from the yellow color, it is ready for the dye. Among those which are recommended are Safranin for red, Chrysoidine R for orange, Auramine for yellow, and Victoria green for green. The dye is ordinarily kept in a stock solution which is diluted 9 to 1 for use. For any of the above dyes dissolve 30 grains of the dye in hot water (about four ounces), then add $1\frac{1}{4}$ fluid drams of glacial acetic acid and make up to one quart. This is a concentrated stock solution. For use, take $1\frac{1}{2}$ fluid ounces and add water to make one quart. This is the working solution.

The time of toning is a control factor, and may vary between two and fifteen minutes. It is usually advisable to dye for at least eight minutes to get a sufficiently strong image, but this factor is subject to experimental proof in your own laboratory.

After dyeing, the film is washed until the highlights are clear. It must be remembered that a color is more easily seen than a light, neutral tone. When there are no small areas in your negative with absolutely no deposit, the entire image will be colored, and you will have to judge by the shadows when washing has been sufficient. As a rule the dye leaves easily, and five minutes washing will often be enough. Rarely will any surplus dye remain in the image after ten minutes washing in running water.

If the dyed image is too heavy, some of the dye may be removed by bathing the film for some time in a 0.2 per cent solution of strong ammonia. After this treatment the film must be washed as thoroughly as at first, for the ammonia frees dye within the emulsion and this must be washed out or there may be dyed patches where they do not belong.

If the dyed image is not strong enough in color, it may, after only a thorough washing, be placed a second time in the mordanting bath and carried through the process like a fresh film.

Many amateurs have been disappointed in dye toning because it would not make a badly grained negative grainless. It is not a magic remedy, but provided a negative of moderate to fine grain is used to start with, this process will reduce the grain to a degree which will usually make possible enlargements twice as large as from the original negative (and even more) with the same degree of graininess apparent in the print.

There are hundreds of other special methods, some of which are useful, many of which are interesting as experiments, and even more which are only "crack-pot" ideas. However, as an experimenter you will search the available literature and the periodicals. When you do find something attractive in theory, give it at least three trials just to see what it is all about. You can't really judge a new process with a single trial, therefore the suggestion that you try it three times.

The wisdom of repeated trials of a new process may not be evident in the case of a process of some value, as careful workmanship will usually show indication of such value at the first trial. But, as there are many so-called "secret and mysterious" processes which are of highly questionable worth, three successive failures will usually satisfy you that there are probably no practical advantages to be gained by such a process.

For example, there are the sugar and glycerin processes. Suggested originally simply as mechanical restrainers, which would act to slow down the penetration of the solution into the emulsion, these admixtures once had considerable vogue as finegrain developers. The idea was to make up a developer with an alkali which had little tendency to swell the gelatin, then to add glycerin or sugar, which would more or less restrict the development to the surface

of the developer; and there you have an early type of surface development.

These substances do have some of the effect ascribed to them, but to a degree which is rarely appreciable, and for that reason the use of sugar and glycerin in developers has largely died out.

VI

HARDENING, FIXING, WASHING, AND DRYING

VI.

Hardening, Fixing, Washing, and Drying

DEVELOPMENT is important, very important, but the photographer usually considers this all taken care of as soon as the film is removed from the developing solution. The steps which follow are considered to be purely mechanical, and little trouble is taken to understand them. This is a highly erroneous attitude; while these subsequent steps do not alter the characteristics of the image as readily as does development, they do have a great effect upon the permanence of the image.

Stop Bath.

Developers are alkaline, while fixing baths are usually acid. Development proceeds in an alkaline solution, and in many cases the quality of the development depends upon the hydrogen ion concentration of the bath (the pH), which is a measure of its alkalinity or acidity. Development ceases when the

solution becomes acid. Therefore, when development is done, it is highly desirable to bring it to an end as quickly as possible. To do this, the film is immersed in an acid solution. The acid concentration must be great enough to neutralize the alkalinity of the developer, which may be as low as pH 6.8 in the case of some finegrain developers, and as high as 12.3 to 12.5 with certain other types.

As a rule the stop bath or short-stop is a two per cent solution of acetic acid or a three per cent solution of sodium bisulfite. If the stop bath is too strong, and if the developer has been compounded with carbonate or hydroxide, gas is generated. The pressure of this imprisoned gas produces bubbles which may, and often do, cause the emulsion to part from the base. The same thing can occur with acid fixing baths. When larger bubbles do not form, tiny ones will, and these will burst to liberate the gas. Such a negative, when dry, is filled with very minute "pinholes," and the surface feels like fine sandpaper.

Often the stop bath is used as a momentary rinse between development and fixing. This is useless, because of the structure of the gelatin. Imagine gelatin to be a thick slice of substance resembling the ordinary laboratory sponge—that is, made up of a huge mass of individual cells separated from one another by walls. The walls are tough, transparent skins, and the contents of the cells is a jelly. There is no visible structure, but this may be taken as the true nature of the substance. Solutions may penetrate the jelly easily, but the walls are membranous. The only way in which solutions can penetrate is by that molecular oozing which we commonly call **osmosis**. After a big-league ball game, the crowd doesn't simply vanish. It leaves the park through the exit gates, and even though the gates are large, it takes several minutes for the crowd to get out. Just so in osmosis, there is free passage

of a kind; yet its very nature restrains the speed of passage so that several seconds may be required to penetrate a few layers.

It is usually assumed that development will continue in the depths of an emulsion for a period of from one-half to one minute after the film has been immersed in a two per cent acetic acid or similar stop bath. Some kind of stop bath should always be used between developer and fixer; in the case of prints its use is essential. When using modern methods it is customary to combine the stop bath with the hardener, but before discussing this we shall give some attention to the general subject of hardening.

Hardening.

Gelatin is one of the most puzzling compounds we have in common use. It has properties shared by no other similar substance in the same degree, and has many physical properties which must be taken into consideration in photographic processing. One of these characteristics is that it will swell, and in swelling take up a great deal of water. This may be crudely likened to a number of small rubber balloons all filled with dry, compressed viscose sponge and all tied together at their necks, but with an opening to admit water. If the comparatively compact mass of balloons is placed in water the sponges will absorb the water and swell, crowding the balloons together and greatly increasing the bulk of the mass.

Just so when gelatin is placed in water, the liquid enters the cells of the gelatin and they expand. They stretch and stretch, until the gelatin is simply a mass of water held in place by delicate cell walls. It is important to remember that this is purely a physical expansion, the extent of which depends largely upon the temperature of the water (or other solution).

If you place a piece of gelatin in water at 60° F. and another piece in water heated to 100° F., the latter will swell far more than the former. However, if you dry both pieces, and after they are dry again place both of them in water at 60° F., they will both swell to their former sizes. That is, once swollen in warm water, gelatin will again swell to that degree when placed in water at any lower temperature.

In swelling, the gelatin simply expands. It does not flow as do other substances. It retains its shape so well that image details as small as 1/1000 inch remain in the same position in gelatin after it has been swollen and dried again. This is one characteristic which makes gelatin so valuable in photography. However, if gelatin is heated when swollen it will go into solution in the water, and this, of course, dissipates all vestige of physical shape. It is important that, in the case of gelatin, we recognize swelling and solution as two entirely distinct phenomena.

When the gelatin is swollen and the cells distended with water, the whole structure is far more delicate than when it is dry. Therefore it is advisable to limit the swelling as much as possible during the process of development. Then there is another factor to be considered. Suppose you glue the edges of a sheet of paper to a board, using waterproof glue. Then if you wet the paper it will expand, and having been fixed at the edges the only way this expansion can take place is by a wrinkling of the paper. Let's carry the illustration further. Take a strip of adhesive tape in your hands, holding the tape stretched between them, sticky side up. Now move your hands together. The tape will drop into a loop, just like the waves in the paper when it was wet. Keep on moving your hands together until the tape touches itself. You now have a loop closed at the bottom, where the tape is stuck to itself. If you pull you may separate the tape some-

what, but instead of breaking free, the attached part travels down toward the end of the loop. At the end of the loop the tape is stuck together in a ridge, and usually the tape will tear before this ridge will part.

What has all this got to do with our problem? Just this: If the gelatin on a film swells too much, it acts like the wet paper because it swells in all directions. Being firmly anchored at the edges of the film base it can do nothing but wrinkle, just like the paper but in much finer waves. A bulge will rise from the film base and keep on swelling until the sides of the bulge which face one another come into contact. Then you are in for it for fair!

When the film is dried, these places where the inside of the wrinkles are stuck together won't let go, and the emulsion dries down with these little seams running in all directions through it. Because of the refraction at these seams, they look like tiny black lines. This is called **reticulation**, and once the wrinkled emulsion has dried there is no remedy. In fact, it is usually a waste of time to try to remedy it even when noticed while the film is wet. If the reticulation is noticed immediately and is not too severe, it may sometimes be eliminated by immediately chilling the emulsion, drying, and then rewashing; but it fails about as often as it succeeds (see Figs. 61 to 65).

The right thing to do is to prevent swelling to a greater degree than is absolutely necessary to permit the invasion of the developer. In fact, the chemical process of development could be adjusted to temperatures between 75° and 85° F. were it advisable; but temperatures in the neighborhood of 70° F. are favorable because they induce a low degree of swelling of the gelatin.

There are certain means of controlling the swelling. They can largely be divided into (a) those which are properly called chemical, and (b) those in which

the action is, strictly speaking, physical although the agent is chemical. Let us consider the latter first.

We have already learned that the addition of neutral salts to a developer will prevent swelling; and we have learned that for various reasons sodium sulfate is about the best agent which can be used for this

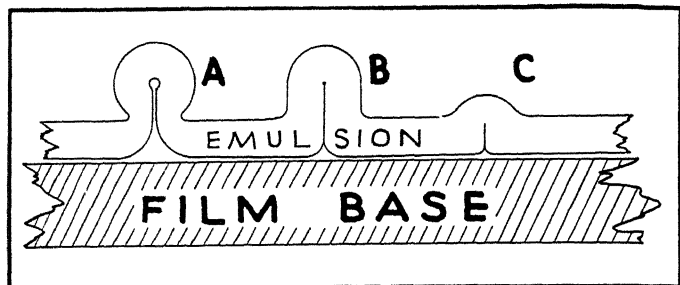


Fig. 61. Reticulation. A, loop of gelatin rises from film base; B, sides of loop adhere, forming line of junction; C, dried gelatin retains junction which forms black line on the negative.

purpose. The explanation is that the neutral salts so affect the osmotic pressure that the gelatin cannot expand. You can force air into a rubber balloon and the rubber will stretch to a great extent, but if you force air into an airtight leather bag, the bag will distend to its fullest size after which the air will stretch it no more. The neutral salts cause the gelatin cells to react more like leather than like rubber, although it must be understood that there is no change in the nature of the cell wall material. The action is purely one of pressure and not of chemical change.

Such effects persist only so long as the neutral salt is present. If the film is washed and transferred to a solution which contains no such anti-swelling agent, the gelatin will promptly swell in the normal manner. Thus, while such agents are often called "hardening,"

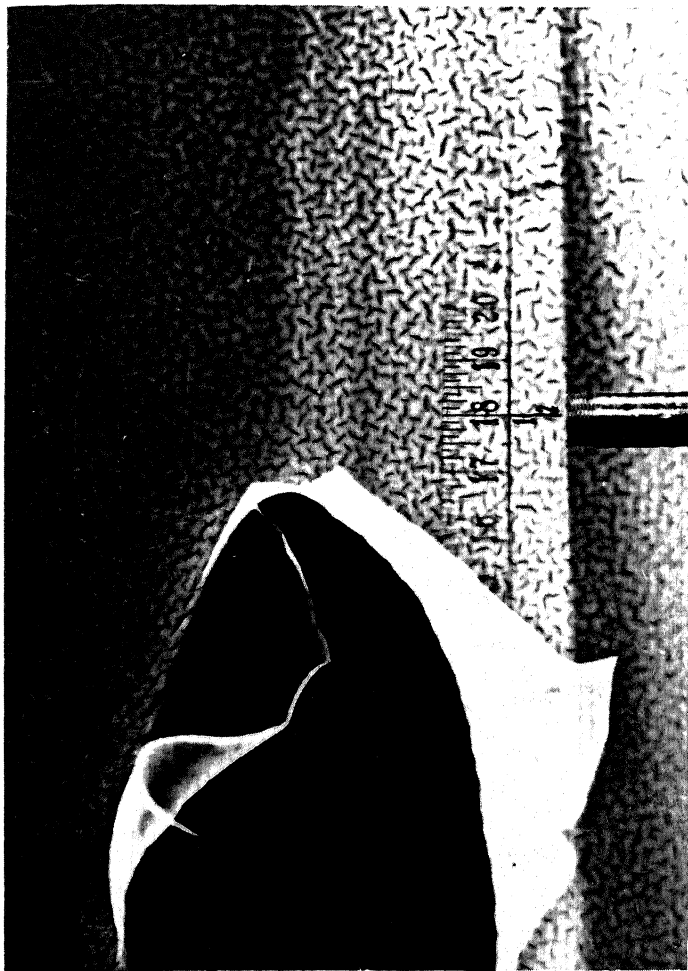


Fig. 62. Print from reticulated negative. Break on bottom shows where emulsion has left film base as result of a large blister.

or more truthfully "temporary hardening," agents, both terms are incorrect as there is no hardening involved whatsoever. There is a distinction between hardening and restraint of swelling which must not be lost sight of.

When it is necessary to carry the anti-swelling to a high degree it is advisable to start the action in the developer. The use of formalin is often advocated, and if the odor is not too offensive, it may be used to advantage. However, while formalin will actually harden the gelatin (a permanent effect), it also induces chemical fog, and may cause a subsequent breakdown of the gelatin. For this reason it is best to use it in a two-bath formula such as has been given in the preceding chapter. In that formula we see the anti-swelling property of sulfate combined with the hardening property of formalin.

The agents most often used for hardening are the alums—**potassium alum** (common or "white" alum) and **potassium chrome alum**. Notice that both of these alums are potassium salts. The latter, however, is commonly referred to as **chrome alum**, so don't be confused when you see the word "potassium" on the label. The action of these salts is not unlike that which takes place in the tanning of leather, in that they cause the gelatin to become much harder than normal. While there are other alums (sulfates which contain two metals in combination), these two are the only ones commonly used in photography.

The choice between the two salts seems to favor the potassium alum even though the chrome alum has the greater hardening power. The chromium salt in any great concentration often leaves a green stain upon the film, and in all events it has a much shorter life than the potassium salt. The chromium alum is most widely used as a constituent of the short-stop—hardening bath used between the developer and the

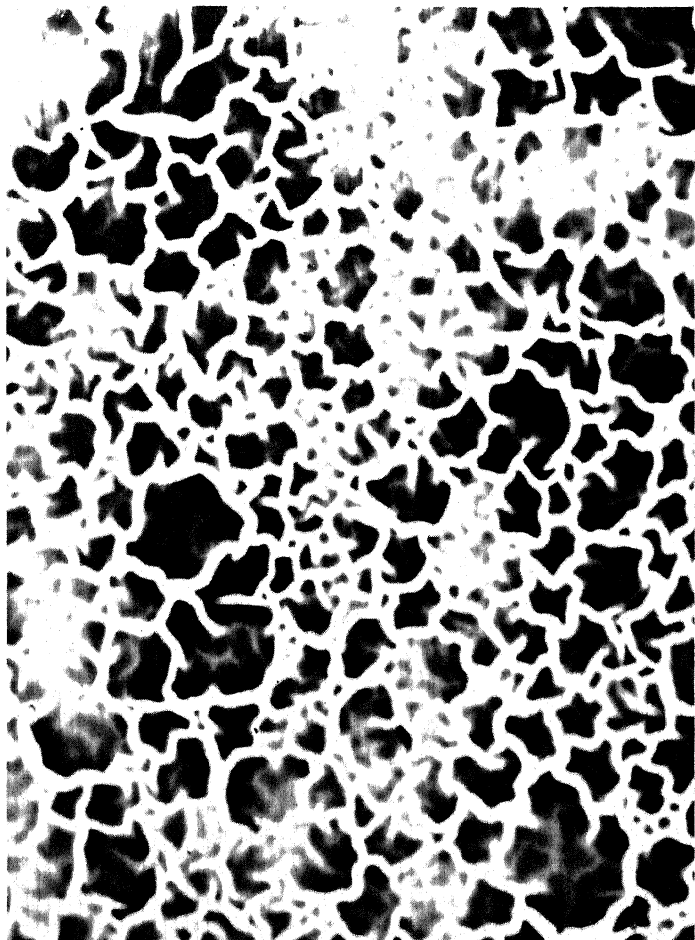


Fig. 63. Portion of a print made from negative which shows advanced case of secondary reticulation; enlarged five diameters.

fixer. This bath should always be made up the same day it is to be used, and as soon as the rich green color begins to take on a yellowish tinge it is to be discarded. The bath is made up according to the following formula:

Short-Stop—Hardening Bath

Chrome alum	135 grains
Sodium bisulfite	135 grains
Water to make	16 ounces

The film is removed from the developer and placed in this bath (intermediate rinsing is not at all necessary), and for the first minute it is agitated continuously. The film remains in the bath four minutes more, with agitation every half minute. After this time the stop bath is removed and the hypo solution added. Rinsing is not necessary at this time either.

It has been suggested that when a developer which contains sulfate has been used, the acid hardening bath should also contain sulfate. The point apparently is to prevent the swelling of the gelatin until the hardening action has set it in place. This is not ordinarily done, and the negatives do not seem to suffer. However, when the temperature is exceedingly high, it might be just as well to add sulfate to the stop bath to the extent of perhaps five or six per cent—that is, by adding one ounce of sulfate to sixteen ounces of hardener.

For many years it has been customary to make use of a fixing bath which contains alum. As we shall see later, this alum is part of a mixture which, simple in itself, has a somewhat complicated reaction. But we are now concerned only with the hardening action, and to this extent the difference between the

stop bath and the hardener in the fixer is that the stop bath usually includes chrome alum and is made up fresh, while potassium alum is used in the fixer and remains stable in solution for a comparatively long period of time.

There is one difference of action which has rarely been mentioned but which should be brought to your attention. It is true that the chrome alum has a greater tanning effect upon the gelatin, but that very property causes the alum to attack the gelatin more vigorously. In some cases where the emulsion has become swollen to an excessive degree, the chrome alum will harden the upper surface into a tough, leathery membrane, while the lower strata remain soft. The memory still lingers of sixteen hundred feet of chrome-hardened motion-picture emulsion slipping from the celluloid base into a mass of sludge in the bottom of the tank!

Potassium alum, on the contrary, appears to penetrate the emulsion and harden it throughout, so that while it seems like a duplication of effort, it is common practice to harden the film in a chrome alum stop bath and then carry it through a fixing bath which contains potassium alum (see Fig. 66).

There has been a great deal of discussion of the advantage of a plain or acid stop bath over the hardening type. The discussion is filled with terms such as "juiciness," "intangible quality," "moist texture," and so forth. The truth is that there is much more basis for such arguments in print making than in negative making. The surface of a print, even to the extent of microscopic texture, does affect the general appearance in ways which cannot easily be described, yet which are strikingly apparent. But in negative making it is probable that no one can distinguish a print made from a hardened negative from one made from an unhardened negative. Of course the negatives themselves are easily distinguished, but the print is the end

of the whole process, and only factors which are apparent in the final print are worth considering. There seems to be no valid objection to the use of alum either in the stop bath or in the hypo, and there is a great deal to be said in favor of both.

So far we have not considered the final type of hardening, that which takes place after washing, and which has been used as a basis for commercial toughening. Such processes are usually given a name which incorporates or suggests the term "scratch-proof." The British Journal of Photography (p. 65, 1940) gives the following formula for scratch-proofing:

Tannic acid	1 part
Hot water	36 parts
When thoroughly cool, add Formalin	4 parts

This is a stock solution which is diluted with fifteen parts of water to each part of stock solution for use. When the film has almost finished washing, immerse it in this solution for five minutes and then continue washing for ten minutes. Any grease or oil, including that left by the fingers, will indelibly mark the surface of the film, so it must not be touched until it is thoroughly dry. Once this film has been dried, particularly if it was hardened during processing, the gelatin will be found actually to be harder than the base, and only a very sharp, hard instrument will make a scratch upon the surface. However, the usual formalin breakdown may be expected in time.

Fixing.

As we have already discussed the theory of fixing, it is understood that the primary object of the process is to remove all the silver compounds which still

retain their sensitivity to light. This, in itself, is a simple matter; there are a number of chemicals, including potassium cyanide, ammonium carbonate, and others, which will do this effectively. Cyanide is undesirable because of its highly poisonous nature, and ammonium compounds are much more inclined to leave stains than is hypo. So for many reasons hypo (**sodium thiosulfate**) is the universally accepted fixing medium.

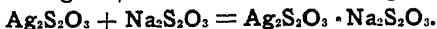
While the removal of the silver compounds will render the image insensitive to the action of **light**, it is not in itself sufficient to insure permanence. All such sensitive compounds may be removed and still leave the image susceptible to changes induced by contact with **air** and **water**, the latter usually in the form of moisture in the air. (Chemical changes presuppose the condition of solution.)

Therefore, the problem of fixing is one of removing the compounds which are sensitive to light, and all other compounds, particularly those of sulfur, which might produce later changes in the composition of the silver image. The change often referred to as "fading" is a result of the change of metallic silver to silver sulfide, a reaction which is often deliberately used in printing to change the color of the image from black to sepia. Therefore, this "fading" may be considered as a process of sulfide toning stretched over a long period of time, and not carried on uniformly over the entire surface of the image.

The action of temperature and concentration has already been discussed in a previous chapter, and it has been learned that while a forty per cent solution of hypo is the most efficient, the concentration ordinarily used in photographic fixing is from twenty to twenty-five per cent.

The fixing action is not a simple matter of solution as would be inferred from the usual explanation. In-

stead of this we have a triple reaction, the end of which is silver disodium thiosulfate.



Silver thiosulfate ($\text{Ag}_2\text{S}_2\text{O}_3$) is not soluble in plain water but it is soluble in a solution of hypo, so that when there is an excess of hypo it is changed into silver monosodium thiosulfate ($\text{Ag}_2\text{S}_2\text{O}_3 \cdot \text{Na}_2\text{S}_2\text{O}_3$), which is another salt soluble in hypo but not in water. But, as it is hypo-soluble, we have still another change taking place, in which this salt is converted into silver disodium thiosulfate ($\text{Ag}_2\text{S}_2\text{O}_3 \cdot 2\text{Na}_2\text{S}_2\text{O}_3$).

The disodium salt is soluble in water, and may therefore be removed by washing the film in water. So we have a coexisting triple reaction the end of which is the water-soluble compound. The disappearance of the silver bromide (the end of the first equation) is marked by the disappearance of the creamy bromide from the emulsion. This is commonly called the **clearing point**. Therefore the changes do not produce any visible change in the film itself. But we know that the instant the emulsion is cleared there still remain quantities of the thiosulfate and the monosodium thiosulfate, and we know that these would not be removed by washing. As they are sulfur salts left within the emulsion, it is only a matter of time until the sulfur and the silver of the image react to produce silver sulfide, and the image turns to a yellowish-brown color—that is, it fades.

It is therefore imperative that the film remain in the fixing bath long enough for the insoluble salts to be converted into the soluble form. Then, and then only, is the film ready for the final washing which will remove the soluble salt.



Fig. 64. In last stage of reticulation, emulsion becomes fluid and image is lost, though there are still light and dark tones.

The time required to accomplish this is ordinarily assumed to be as long as was required for the first stage. That is, if the film clears in three minutes, it is fixed at the end of six minutes. This is a liberal estimate, but it is advisable to use too much time in fixing rather than to have a valuable negative lost through subsequent fading.

Remedy for Fading.

If a negative does fade, the best remedy is to bleach the image and sulfide it, just as you would proceed in toning a print sepia. In doing this the sulfiding is not only brought to completion and made uniform throughout, but the sulfide added in the second bath builds up the image and produces one which in many cases has all the printing strength of the original; in some cases the slight intensification actually improves the negative. As there is often a destructive softening of the emulsion, the film should be hardened if it was not so treated during the original development.

In case you are not familiar with sepia toning, the usual cold method is to bleach the image, then change it to sulfide by flowing over the bleached film a solution of sodium sulfide. NOTE that this is sulfIDE and not sulfITE.

Bleaching Solution

Potassium ferricyanide.....	¾ ounce
Potassium bromide.....	¾ ounce
Water to make.....	16 ounces

As you will discover later, there is a solution made of potassium ferricyanide and hypo which removes the

image entirely. This is known as **Farmer's Reducer**. If there is any trace of hypo in the negative, the ferricyanide of the above bleach will react with it to produce this solution, and instead of bleaching the image, it will be entirely removed. It is essential, therefore, that the negative be thoroughly washed before it is bleached. The negative is left in this bleach for three or four minutes. The exact time is that required to remove the last trace of black from the image, leaving it a grayish to yellowish color. It is then rinsed and the sulfide solution is flowed over it.

Sulfide Solution

Sodium sulfide.....	88 grains
Water to make.....	10 ounces

Agitate the film in this solution until the color no longer deepens. The actual color may vary from a distinct yellow to a rich sepia. After toning, wash the film thoroughly for about twenty minutes. If the surface has the slightest slippery feeling, the gelatin should be hardened in the usual hardening bath.

The subject of toning brings up the factors involved in hypo alum print toning. The name "hypo alum" suggests the hardening-fixing bath, and this is just about what it is. Any such bath, once the sulfur has been precipitated, will alter the image to silver sulfide, turning it sepia at the same time. The time required is about twelve hours, but by heating the bath it may be made to work in a few minutes. A typical formula is shown on the next page. The bath will operate without the silver solution. It is a muddy bath which is not filtered, but is stirred up before each period of use. When kept at a temperature about 100° F. or slightly warmer, toning requires something less than a half-hour.

Hypo Alum Toner

Hypo.....	2 ounces
Hot water to make.....	10 ounces
Dissolve and add:	
Potassium alum.....	½ ounce
Boil for three minutes, then cool to about 150° F., and add:	
Silver nitrate.....	5 grains
Sodium chloride.....	5 grains
Water.....	1 ounce

Add strong ammonia one drop at a time, stirring vigorously until the precipitate which forms at first is just dissolved.

This process is only of academic interest to us at this time, as we are concerned with negative making. While the sulfide toning is valuable as a means of saving faded images, the hypo-alum method is given only to show that hypo and silver are enough to produce toning (fading).

You will often hear arguments as to which error is responsible for fading—the lack of complete fixing or the lack of thorough washing. If the fixing is incomplete, insoluble silver-sulfur salts remain in the emulsion adjacent to the silver image; while if washing is not thorough the emulsion will retain a salt of sodium and sulfur (hypo) also adjacent to the silver image. It would appear that fading to the yellow of silver sulfide might well follow either omission.

Hypo and Other Agents.

Abney, in his work referred to in Chapter II, informs us that the use of potassium cyanide is not attended by the danger of the residual complex salts, as the reaction is then simply:



The silver cyanide is readily soluble in the presence

of a potassium salt, so the compound is readily removed by comparatively short washing. However, as has been pointed out, the slight advantage gained by the use of cyanide is far more than offset by the grave danger of using the cyanide. Even when it is kept in the workroom the fumes will often produce serious illness. Although it is used in certain advanced processes, there is no reason why the amateur should ever make any use of this salt.

About the only fixing agent other than hypo which the amateur may want to use is ammonium chloride, which we will see is sometimes used with hypo as a rapid fixer in spite of its propensity for staining.

Our greatest attention will be given to hypo. This name is left over to us from the days when the chemical was known as "sodium hyposulfite." Hypo is actually the sodium salt of thiosulfuric acid ($\text{H}_2\text{S}_2\text{O}_3$), an acid which is more important in theory than in physical existence. It can be seen that it differs from sulfuric acid in having one less oxygen atom and one more sulfur atom. Thiosulfates are sometimes described as sulfates in which this change has taken place in the SO_4 radical (one "O" replaced by one "S").

Hypo, as we shall continue to call sodium thiosulfate for the sake of convenience, is made up of white (colorless), monoclinic crystals which are highly soluble. Like many other salts used in photography, hypo can be dehydrated and produced in the anhydrous form. However, there is no particular advantage in doing so, and the anhydrous hypo is many times more costly than the crystalline form.

Addition of Acid.

The entire chemistry of photography involves a conception of chemical principles which may be new to

those who have not had chemical training beyond the usual high-school instruction. Any chemical may profoundly alter its character when dissolved, such alterations involving the "ionization" of the salt. Also, many photographic reactions are based upon the formation within the solution of totally new compounds. When one stops to realize that the change of position of a single atom within the molecule from one place to another can alter the identity of the compound, the great differences produced by the complete absence or addition of a single atom can be more fully appreciated. Every student of photographic chemistry should become familiar with Yoe's "Chemical Principles," in which much of this, particularly, the phenomena of ionization, is fully explained.

As chemicals in solution react differently from the dry forms, it is not surprising that hypo should slowly change in solution. As can be ascertained both from the name of the salt and its formula $\text{Na}_2\text{S}_2\text{O}_3$, hypo is a salt of sodium and sulfur. In solution sulfur is deposited and sodium sulfite is formed in small quantities (Na_2SO_3), the deposition of sulfur from the hypo leaving the sulfite as a result of the change ($\text{Na}_2\text{S}_2\text{O}_3 \rightarrow \text{Na}_2\text{SO}_3 + \text{S}$).

If an acid is added to hypo, decomposition starts in at once. Sulfur is deposited, and sulfur dioxide, hydrogen sulfide, or both are formed and liberated. Within the solution there is a formation of sodium sulfate and thionates with the result that eventually the hypo is entirely destroyed. The sulfur is deposited very slowly, and at first it gives a slight bluish turbidity to the solution—very slightly blue and very slightly turbid. The condition is often spoken of as being "slightly smoky." Later on as the sulfur increases in quantity there is a definite creamy turbidity and finally a yellowish precipitate.

When any hypo solution begins to have this smoky

appearance, even to the slightest degree, and when it has the first suggestion of a foul odor, it has started to decompose. Then, regardless of its age or the amount of service it has seen, it should be discarded and a fresh solution made up. There are, of course, exhaustion tests. One such test is as follows: To a quantity of the solution add one-tenth its volume of a four per cent solution of potassium iodide. A permanent yellow precipitate indicates an exhausted bath. A simpler method is to put a drop or two upon blotting paper and expose it to sunlight. A brown color indicates exhaustion. The test should be continued for at least fifteen minutes before accepting the result as negative.

A fixing bath may become exhausted because of the breaking down of the hypo itself, in which case there is the visible indication of the precipitated sulfur; or it may become so heavily charged with the removed silver from previous emulsions that it will no longer act. In either case it should be discarded.

There are two exceptions to the rule that acids and acid salts will decompose hypo. Boric acid and sodium bisulfite will not do so. Therefore, if sulfite is added to the hypo solution, weak acids may be added also without precipitating the sulfur; as long as there is an excess of sulfite to be converted to bisulfite the sulfur will not be precipitated. This is of decided advantage in making up compound baths, as it enables us to acidify the hypo without disastrous results. As we shall see, the borax is also a valuable addition to the bath.

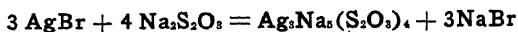
Alkaline solutions of hypo have no appreciable effect upon the image. Neutral hypo solutions have very little effect, but an acid solution of hypo has a distinct reducing action, so much so that within as short a time as forty-eight hours, if conditions are right, the hypo will bleach the image out entirely.

This is a factor of considerable importance, as it indicates that the usual working solution of hypo may attack the more delicate tones in a comparatively short time. This is true, so we have a maximum as well as a minimum limit for the time of fixing.

The Use of Hypo in Photographic Processing.

Let's get on to the discussion of the use of hypo in actual photographic processing. We have followed the reactions of silver bromide when placed in a quantity of hypo. When there is only a small amount of hypo available the reaction terminates with the first phase, namely, the production of silver thiosulfate. This product is unstable and breaks down into silver sulfide (Ag_2S) and, in the presence of water, sulfuric acid. The sulfide is brown to brownish-black and is insoluble. This is the brown stain seen upon prints when they float near the surface of the hypo, with perhaps one corner sticking above the solution. The same stain is formed when a finger moist with hypo touches a sensitized surface.

It is when the hypo solution is in **excess** that the more complex salts are formed. It might be added that the equations given are probably correct, but as authorities disagree upon the point, we may as well point out the other side of the argument which is this:



—and that in the presence of an exhausted or weakened solution the insoluble salt AgNaS_2O_3 is formed. In either case when the insoluble salt is formed in the emulsion it may be removed at a later date, either a few seconds later or a few months or even a few years, by immersing in fresh hypo. However, silver bromide which has broken down spontaneously into silver



Fig. 65. Effect of heat and softening. Emulsion has left base, upper right; note primary and secondary reticulation, upper left.

under continued light action cannot be removed thus, nor can any of the silver sulfide which may have resulted from the breaking down of the original silver thiosulfate.

We have seen that certain factors affect the rapidity of the hypo action, including the temperature, the concentration of the bath, and other minor factors. But there are still others involved. It should be understood that the hypo removes a constant fraction of the total bromide in each successive unit of time. The size of this fraction is indeed dependent upon the temperature and the concentration of hypo in the solution; but it is not dependent upon the silver content of the emulsion, nor is it affected by any degree of swelling or by previous hardening of the film during processing.

The finer the grain size the more rapidly the solution will act, so that finegrain images will be fixed more rapidly than coarser ones. The various halides also act differently. Iodides are difficult to remove. Bromide is much more easily removed than the iodide, while chlorides are most easily of all removed by hypo. For example, in a mixed emulsion of iodide-bromide, the bromide is almost all removed by the time the iodide is just beginning to respond. This fact was confirmed by E. R. Burdock, who reported his experiments in England in 1922.

So we have a regular progression of the rate of bromide removal. For example, if half the bromide is taken out the first minute, half the remainder will be taken out the second minute, half the remainder the third minute, and so on. Using this hypothetical ratio we should have this result:

Minute	Removed	Remainder
1	$\frac{1}{2}$	$\frac{1}{2}$
2	$\frac{1}{4}$ ($\frac{1}{2}$ of $\frac{1}{2}$)	$\frac{1}{4}$
3	$\frac{1}{8}$	$\frac{1}{8}$
4	$\frac{1}{16}$	$\frac{1}{16}$

We could go on and show that at the end of each successive minute the remainder would be: 5...1/32; 6...1/64; 7...1/128; 8...1/256; 9...1/512; 10...1/1024; and so on. At the end of ten minutes the amount of hypo remaining would be about one-tenth of one per cent.

According to the above scale, if the bromide were removed at the rate of half its volume every minute, the end of the sixth and seventh minutes would set limits between which 95 per cent of the bromide would be removed. It is generally accepted that the disappearance of the visible bromide marks the elimination of 95 per cent of that salt. It is also accepted that using this time as standard, fixing for just that much longer time would naturally remove 95 per cent of the remaining 5 per cent of the original amount, or $4\frac{3}{4}$ per cent leaving behind only $\frac{1}{4}$ per cent of bromide in the emulsion. We know from experience, however, that the time required for clearing is usually about three minutes, so that in six minutes the original bromide has lost $99\frac{3}{4}$ per cent of its original volume, and this residue is sufficiently small to be truly negligible for all practical purposes.

While we have been discussing chemical reactions and rate of removal of the bromide so freely, we have neglected to consider what really takes place in the hypo—not the chemical reactions alone, for we have considered a part of them, but what happens in the actual practice of fixing. When the film has been placed in the hypo, the emulsion is filled with developer which goes right on developing unless it has been through a hardening-stop bath, and even though it has been carefully rinsed. This will continue as long as there is any developer left in the emulsion, unless the alkalinity of that developer is neutralized. If it does go on unchecked, the varying amounts of developer in various parts of the emulsion will produce uneven development. But

that is not all. The oxidation products of development will discolor the hypo and this, in turn, will stain the negative. Worst of all, the deposit of **dichroic fog** is to be expected when the hypo becomes strongly contaminated by developer. Just to make matters more complex, the bath will throw down brown silver sulfide which will make an almost indelible stain upon the negative, metallic silver will be deposited, and the emulsion will become greatly swollen and soft.

This is a true picture of what does happen when a plain hypo bath is used for any length of time, particularly if negatives are simply rinsed between the developer and the hypo. It must be plainly understood that we are not discussing the problem of fixing as related in any way to printing. With that warning it should be reasonable to state that whatever may be the advantages of the plain hypo bath, they are far outweighed by its several disadvantages. The principal objection to the acid bath is that exhaustion is not very obvious. The plain bath does show exhaustion, usually by staining a batch of negatives. We can do without such a warning, and as for knowing when the bath is exhausted . . . well, when a small roll of film costs a quarter there is no sense in saving half a cent by prolonging the life of a fixing bath by perhaps a week! Remember that a roll lost is that much investment of both time and money lost!

Acid Salts.

The obvious remedy is the addition of an acid salt to the hypo, and either sodium bisulfite or potassium metabisulfite is usually chosen for the purpose. A quarter ounce of the acid salt is added to every ten ounces of plain hypo—an acid salt strength of two and a half per cent by weight. It is decidedly better for the purpose than plain hypo, but even the acid hypo is not

very satisfactory as it slowly throws down sulfur on standing. It is used, however, in some processes where the emulsion cannot be hardened in the least, such as making gelatin reliefs for oil printing and in color work. But again, that is in the field of printing.

It has been shown that when a non-hardening hypo bath with an acid reaction is desired, the best results are obtained by the addition of acetic acid and sodium sulfite. This reaction has already been mentioned, but we did not point out that the transformation of sulfite to bisulfite also produced sodium acetate through the combination of acetic acid and sulfite. This continuous reaction provides a reserve of acidity, just as carbonate provides a reserve of alkalinity in a developer. Thus, we have a continuous addition of acid to the hypo to counteract the continuous addition of alkaline developer.

It was also mentioned that boron may be added to the hypo in the form of a borate (borax) or of boric acid without the usual reaction to an acid. As a rule the reaction of the hypo bath is about pH 4.2 when freshly prepared, and by the time this reaches pH 4.8 the bath is virtually exhausted. However, the presence of boric acid prevents the forming of the sludge of aluminum sulfite, and maintains the hardening property of a hardening hypo bath up to about pH 5.8 to 6.0.

Therefore, we may judge that any hypo bath may be vastly improved not only in action but in keeping qualities by the addition of acetic acid, sodium sulfite, and boric acid. Experience has proven the wisdom of these additions.

The Hardener.

We have still omitted one very important factor which was discussed at the opening of this chapter—the hardening. The acetic acid and sulfite have been

purposely discussed first and together because they belong together. Theirs is a separate function, and in a measure they stand entirely apart from the hardening agent. Ordinarily some astringent chemical, such as an alum or tannic acid, is used for this purpose. There has always been a certain amount of favor given to formalin as a hardening agent, but its value is questionable.

Formalin is a solution of formaldehyde, which has a very unpleasant odor and which often acts as a severe irritant to mucous membranes and particularly to the eyes. These objections might be overcome by careful handling. In fact the Eastman Research Laboratory has provided a formula for a hardener based upon formalin rather than alum for use at very high temperatures. The principal objection to the bath as such is the fact that a hypo solution containing a formalin hardener is only good for about a week at temperatures above 95° F. This hardener-hypo is somewhat different from the usual run of hypo formulas, as will be seen

Formalin Fixing Bath

Hypo	5 ounces
Sodium sulfite, desiccated	1 ounce
Formalin	2½ fl. oz.
Water to make	20 ounces

It will be seen that the concentration of hardener (formalin) is unusually high in proportion to the hypo, even though the latter is in the usual twenty-five per cent concentration. The formula calls for a small amount of solution because it is advisable to make this up, use it one day, and then to discard it. When formalin is used the negatives will not, in all probability, be permanent. The gelatin becomes very brittle in time and leaves the base in scales and powder. It should

therefore be used only with negatives of temporary value.

The usual formula for a hardening hypo bath is one or the other of the following, the potassium alum being recommended over the chrome alum despite the statement so often made that chrome alum is **always** used in the tropics. As a matter of fact, many tropical workers use the same potassium alum formula used in temperate climates.

Kodak F-1—Fixing Bath

Water.....	64 ounces
Hypo.....	16 ounces

To this add the hardener made as follows:

Water.....	5 ounces
Sodium sulfite, desiccated.....	1 ounce
Acetic acid, 28%.....	3 fl. oz.
Potassium alum.....	1 ounce

Dissolve all chemicals of the hardener thoroughly before adding to the hypo solution. This formula, under various names, is published by practically every manufacturer of emulsions and chemicals. It is the old-time standard. The chrome alum formulas differ only slightly, and as a type we can use the Kodak F-16:

Kodak F-16—Chrome Alum Fixing Bath

Hypo.....	2 pounds
Sodium sulfite, desiccated.....	2 ounces
Water to make.....	90 ounces

Hardener:

Water.....	32 ounces
Chrome alum.....	2 ounces
Sulfuric acid, C. P.....	1/4 fl. oz.

Pour the hardener into the hypo while stirring vigorously. This bath must be used fresh. Old baths have little or no hardening power, and tend to deposit a scum on the surface of the film, which scum must be removed by thorough scrubbing with cotton before drying.

Neblette, to whom reference has been made in Chapter I, points out difficulties which may be encountered when using the first of these baths. These difficulties are all concerned with the milkiness which may appear after the bath is a few hours old. It may be caused by (a) too much or too strong acid (formulas all call for 28%); (b) too little sulfite, either in actual quantity or because the sulfite used has deteriorated; (c) too high a temperature; or (d) incorrect mixing.

The foregoing objections are based upon sound principles, and may be demonstrated experimentally in the laboratory. Glacial acetic acid may be used, provided it is used properly. I have not used the dilute acid for twenty years, and have no trouble whatsoever with baths going bad except through exhaustion.

Practically all formulas for potassium alum hypo solutions give first the full quantity—that is, 32, 64, or 128 ounces, the extreme capacity of the bottles ordinarily used in the laboratory. To these quantities are added the hardener. This may be a minor problem, but it is an irritating one to the amateur. Therefore, a solution is offered which is unorthodox, but one which has provided freedom from fixing and hardening troubles over a period of many years.

To make a half gallon (64 ounces) of hypo, dissolve 16 ounces of crystal hypo in 45 ounces of water. This is not critical; just take an amount which is between $2\frac{1}{2}$ and 3 pints. Place the hypo in a small cloth bag, such as a well washed sugar bag. Any lightweight cotton cloth will do as long as it is fairly closely woven. Suspend this in the container of water so that the bag is barely submerged. The hypo will dissolve,

and as hypo solution is much heavier than water, it will sink, pushing fresh water upward. This automatic replacement will produce complete solution of hypo in less time than it could be done by pouring the hypo into the container and then stirring (see Fig. 35, Chapter III).

While the hypo is dissolving, dissolve 1 ounce of dry sulfite in 7 ounces of water, add 1 ounce of glacial acetic acid, then dissolve in this solution 1 ounce of potassium alum. When solution is complete, add it to the hypo solution and make up the total to 64 ounces. Thus instead of 72 ounces of total solution, you have 64 ounces, which will be accommodated by the usual half-gallon bottle. Not only this, but you have a true 25 per cent hypo solution instead of the 22.22 per cent solution obtained by adding the 8 ounces of hardener to the 64 ounces of hypo.

Not only does this work with entire satisfaction, but it is easy to remember. Hypo equals one-fourth total volume, hardener contains 1 ounce each of sulfite, acid, and alum.

In the tropics there is often present a liquefying bacterium which likes nothing better than a juicy meal of gelatin. An ordinary solution of gelatin which has "set" will be converted into a non-setting fluid by these organisms, and negatives will often present a surface crisscrossed by crooked trails where the gelatin has been liquefied to the base. This happens during the drying period, which is generally quite long in a humid climate. When emulsions are hardened in the bath just mentioned, they may be hung with complete safety in the direct tropical sunshine, which will dry them in short order. Once dried, the negative is usually safe from the bacteria unless the emulsion is allowed to become quite damp.

The beginner is often warned against this very trick of drying films in direct sunshine, but I have

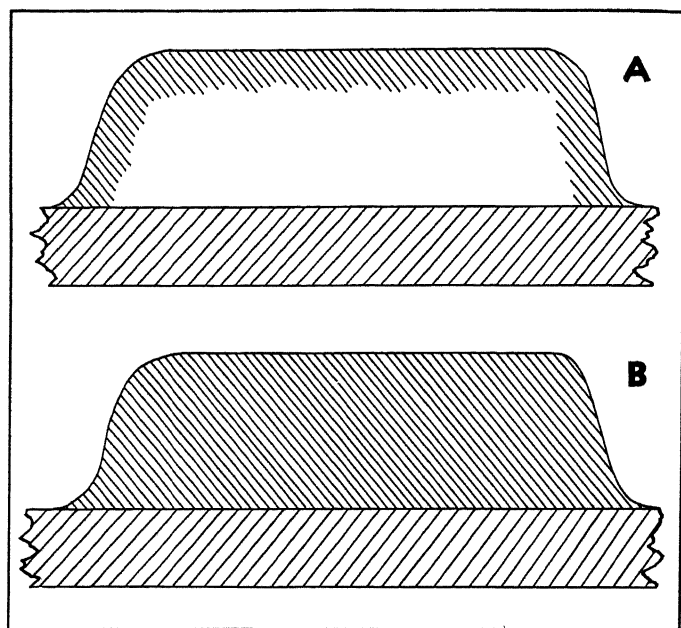


Fig. 66. Chrome alum may harden surface gelatin and leave under layer soft (A); potassium alum hardens the gelatin throughout (B).

never yet had a single instance of the emulsion running, although I have used the method consistently in the tropical and subtropical regions of this hemisphere. On the contrary, negatives have been processed at 90° to 95° F., including ample washing, without reticulating. Once a fresh hardening hypo solution gets in its action upon an emulsion, the gelatin takes on an unusually high degree of hardness.

In recent years it has become routine to make use of hardening-fixing baths containing boric acid. As has been stated, this addition extends the hardening

power of the bath to a far less acid condition than when it is not used. However, this is not too important, as the greatest factor of all in successful fixing is the use of comparatively fresh solutions. The boric acid has a tendency to maintain chemical balance at all times (as a buffer), and for that purpose definitely increases the value of the solution. One example of this is the Kodak formula F-5a, which is an acid hardening stock solution (hardener only; no hypo):

Kodak F-5a—Hardener Stock Solution

Sodium sulfite, desiccated.....	2½ ounces
Acetic acid, 28%.....	7½ fl. oz.
Boric acid, crystals.....	1¼ ounces
Potassium alum.....	2½ ounces
Water to make.....	32 ounces

The 1¼ ounces of boric acid may be replaced by 2½ ounces of Kodalk, or double the quantity. Such a solution is known as the Kodak F-6a Hardener. For use, in both cases, add one part of cool stock solution to four parts of cool hypo solution (30%, or 2½ lbs. per gallon of sol.) while stirring rapidly. There are various formulas for fixing baths which call for the use of sodium tetraborate and sodium metaborate, both salts of boric acid. The purpose of such substitution is ordinarily to prevent the formation of sulfur dioxide. These fumes have an unpleasant odor, and are almost invariably present when boric acid as such is added to the solution. Baths in which the salts are used are commonly designated as **odorless** fixing baths. Several fixing bath formulas, all of which incorporate slight variations that make them more suitable for special purposes, will be discussed later.

Capacity of Fixing Solution.

We have had much to say about using fresh baths

and about the exhaustion of the fixing bath. Therefore, it would be interesting to know something about the actual capacity of a fixing solution. This has always been a matter of interest, and a half century ago experiments were conducted which gave as the solvent power of a liter of 20 per cent hypo the following: 91 grams of silver chloride; 78 grams of silver bromide; 10 grams of silver iodide. If we assume that the average $3\frac{1}{4} \times 4\frac{1}{4}$ film contains 0.25 grams of silver bromide, which is not too far from the fact, one liter (slightly more than one quart) of hypo would fix out 312 such films, or 26 dozen. We know from experience that this is far more than the normal 25 per cent solution will fix; so where is the discrepancy?

The experiment was made with solutions only and carried to saturation. In actual fixing we have a solution which contains chemicals other than hypo, and despite the actual concentration of hypo, these additions decrease the fixing capacity. Moreover, we cannot carry the reactions to exhaustion because we know that when the hypo bath has fixed a sufficient number of films to have a concentration of two per cent silver salts in solution, it will no longer convert a safe quantity of the complex thiosulfates which must be removed before the film can be considered permanent.

Without going into details of the experimental results obtained with actual photographic materials, it may be said that about 350 $3\frac{1}{4} \times 4\frac{1}{4}$ films can be fixed safely in each **gallon** of 25% hardening hypo, and still leave an ample safety margin. It will be noticed that this is only about one-fourth the capacity indicated by the straight solution test. Reducing this to square inches we have a normal fixing capacity of somewhat under 5000 square inches per gallon. Actually this may be extended to about 7500 within the margin of safety, but it is good practice to limit the use of the bath to about 5000 square inches per gallon.

The average amateur uses a half-gallon storage bottle and some only one quart; the following table shows the life of a unit of hypo solution in terms of some familiar negative sizes:

Film	Sq. In.	1 Gal.	½ Gal.	1 Qt.
35 mm	82.5	60	30	15
(5 ft.)				
120 roll	78.5	64	32	16
2¼ x 3¼	87.75	56	28	14
(doz.)				
3¼ x 4¼	165.75	30	15	7
(doz.)				
4 x 5 (doz.)	240	20	10	5

In the above tabulation fractions have been rounded out, and in each case the lower remaining whole number has been taken. It would be advisable to post in the darkroom a check chart divided into the correct number of squares, according to the amount of hypo solution kept on hand. There is sufficient latitude that, in case you use mixed film sizes, one chart will do the trick for all these sizes. Check one unit for each 35 mm, 120 roll, or dozen of 2¼ x 3¼; check two units for each dozen 3¼ x 4¼; and check three units for each dozen of 4 x 5. It is sufficiently close to consider a 127 roll as a half-unit roll, as it has a surface area just about half that of the 35 mm film. Remember that the area is not limited to the picture area, but must include the entire surface of the film. After the chart has had all squares checked, a fresh batch of hypo is indicated.

The hardening-fixing bath using boric acid and potassium alum is a good universal fixing bath for negatives. It is even an advisable bath to be used after a bisulfite-chrome alum stop bath. But there are times when it is desirable to hasten the fixing action, and for that purpose a somewhat different bath is used. There are a number of substitutions possible in photographic chemistry. Among these we have

noticed the use of chemicals other than hypo for the purpose of fixing, including **potassium cyanide** and **ammonium thiosulfate**.

The ammonium salt has two advantages in that it works much more rapidly than hypo, and its optimum fixing concentration is fifteen per cent instead of the forty per cent which marks the most efficient hypo concentration. The fact that the ammonium salt costs roughly ten times as much as the sodium salt is often given as the reason for using the latter; but this is not the whole reason. The complex thiosulfates resulting from the use of the ammonium salt are even more difficult to deal with than those resulting from the use of hypo, and staining is more often encountered. However, it has long been known that the addition of ammonium chloride to the hypo bath in a concentration of about five per cent will give the hypo an increased rate of action similar to that found with the ammonium thiosulfate.

It is noticeable that the effect of the ammonium grows proportionately less as the hypo concentration is increased, and with a hypo solution of forty per cent (maximum activity), the addition of ammonium chloride seems to have very little effect. It has therefore been suggested that the addition of the chloride simply serves to convert hypo into ammonium thiocyanate. Careful investigation, however, has shown that this is not the case. For any concentration of hypo there is a corresponding amount of chloride which can be added to the best advantage. Any amount more than this (which should react to provide even more ammonium thiosulfate) slows down the action again. Therefore, there is some action involved which is definitely different from the use of straight ammonium thiosulfate. The double salts formed are less stable than those formed in hypo, and the bath has not nearly as much life as has the straight hypo bath.

Similar results are obtained by adding a ten per cent solution of ammonia to the hypo bath, but this is rarely done as **any** ammonium salt tends toward the formation of dichroic fog, and the liquid ammonia is worse in this respect than the chloride. After all, when a film can be thoroughly fixed in from six to eight minutes, what is gained by cutting off two or three minutes at the risk of losing the negative?

Summary

As we now have a fairly clear picture of the fixing process, just what does it suggest in the way of a summary? There must be some **fixing agent** which will combine with the silver bromide, transforming it into a compound which is soluble in water. This need not be a true solution of the silver bromide, nor is it in practice. This agent must have a very slight effect upon metallic silver, the less of such action the better. The agent must be safe, inexpensive, and convenient to use.

From those available, the cyanides are too poisonous although highly efficient, especially where iodides are concerned. Among the thiosulfates, both the sodium and the ammonium salts are available. The ammonium salt is unpleasant to use, is comparatively expensive, and has a tendency to stain. The cheap sodium salt, while less active than the ammonium salt, does a satisfactory job and has no great disadvantages. Therefore sodium thiosulfate is universally used as a fixing agent for bromide and chloride emulsions.

There are certain additions available which will increase the activity of the sodium thiosulfate, such as ammonium chloride and ammonium hydroxide in weak solution. Both have a tendency to stain and a much shorter life than the standard solution. As the liquid ammonia stains more than the chloride, the latter is

used when such addition seems vitally necessary. Ordinarily, however, no such additions are made to the hypo solution.

The hypo has a tendency to throw down sulfur, and to prevent this it is usual to add a preservative. While certain alkaline salts such as sodium acetate or sodium citrate may be used, it is customary to make use of the sodium bisulfite and/or sodium sulfite. Sodium acetate is satisfactory, but the sodium citrate has a tendency to act like citric acid. Citric acid will remove the "tanning" from a hardened emulsion, restoring its ability to swell when placed in water. The usual agents are bisulfite in a simple acid bath or sulfite in the combined hardening bath.

Some agent is desirable which will neutralize the alkalinity of the developer, help to prevent stains and dichroic fog, and act against the excessive swelling of the gelatin which would take place if the bath were to become alkaline. It has been said that almost any acid can be used for this purpose, but we have seen that the addition of an acid too often precipitates sulfur, sometimes even in the presence of the sulfite preservative.

In the ordinary acid baths we have the acid salts, sodium bisulfite and potassium metabisulfite, playing the part of stain preventive. In the hardening hypo bath we may have either of these salts, acetic acid, sulfuric acid, or any one of many organic acids. We have already seen that citric acid, although it will act in this way, at the same time works against the hardening action of the alum. So for many reasons the anti-stain agents which are actually used in common practice are acetic acid, sulfuric acid, sodium bisulfite, and potassium metabisulfite. Of these the acetic acid is most widely used, and is thoroughly satisfactory.

In the line of hardening agents we have several, among which we do not include neutral salts (such as sodium sulfate) simply because they are **anti-swelling**

agents and not **hardening** agents. Their effect ceases as soon as the film is removed from their solution. The actual hardening agents include the salts of ammonium and chromium (the most commonly used of which are the "alums"), formalin, and tannic acid. Formalin has a tendency to make the emulsion so brittle that it will crack and powder. Tannic acid is used principally as a final hardener in "scratch-proof" treatments. The alums commonly used are the white or potassium alum and the purple or chrome alum. The white alum has a long life which may be considerably extended by the addition of boric acid (or a borate). It is the most widely used hardener in hardener-hypo baths.

Chrome alum hardener has a comparatively short life, even when it is not used. Although it has a hardening power actually higher than the potassium alum, on highly swollen emulsions it tends to harden the surface, leaving the base soft. It is an excellent hardener to use between developer and hypo, and is therefore a favored constituent of the hardening stop bath.

Formulas.

Now let us see what some of the manufacturers recommend in the way of short-stop and fixing solutions.

Agfa 201—Acid Hardening Fixer

Solution 1.	
Hypo.....	8 ounces
Hot water..	16 ounces
Solution 2.	
Hot water.....	5 ounces
Sodium sulfite, desiccated.....	½ ounce
Acetic acid, 28%.....	1½ ounces
Potassium alum.....	½ ounce
Mix 1 and 2, add water to make.....	32 ounces

In this formula allowance has been made for the hardener, so that the total volume comes to 32 ounces. Notice that hot water is specified. This is usual because the hypo going into solution makes what is commonly termed a **freezing mixture**—that is, the solution gets very much colder than the original temperature of the water.

Although no particular advantage is claimed for the procedure, I have always made a habit of using water at room temperature, provided that it is not below 65° F., for all photographic solutions, and thus have avoided any decomposition which might result from having the water too hot. But to proceed with the formulary: Agfa presents another fixer, Number 202, which contains chrome alum.

Agfa 202—Chrome Alum Fixer

Solution 1.

Hot water.....	80 ounces
Hypo.....	2 pounds
Sodium sulfite, desiccated.....	2 pounds
Water to make.....	96 ounces

Solution 2.

Chrome alum.....	2 ounces
Water.....	32 ounces

Dissolve and add:

Sulfuric acid, C. P.....	¼ ounce
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Stir vigorously while adding the acid drop by drop. Pour solution 2 into solution 1 while stirring rapidly, and do not dilute for use. Normal fixing time 5 to 10 minutes. **WARNING!** Do not have water above 150°F. for dissolving the chrome alum!

In the line of straight acid fixers we have the following:

Agfa 203—Non-Hardening Metabisulfite Fixer

Hypo.....	2 pounds
Potassium metabisulfite.....	4½ ounces
Water to make.....	64 ounces

The solution must be cooled before adding the metabisulfite. Dilute the above with an equal quantity of water. Normal fixing time about 5 to 10 minutes.

Agfa 210—Acid Short-Stop Bath

Acetic acid, 28%.....	1½ ounces
Water to make.....	32 ounces

Agfa 216—Chrome Alum Hardening Bath

Potassium chrome alum.....	1 ounce
Water.....	32 ounces

Films must be agitated when immersed in the hardener and the solution allowed to act for about three minutes. The solution is to be made up fresh as it does not keep. The addition of ½ dram sulfuric acid will prevent the formation of sludge. Now we come to a formula proposed by E. J. Wall and approved by Sir William Abney:

Hypo.....	4 ounces
Water to make.....	16 ounces
Add to the above:	
Citric acid.....	¼ ounce
Sodium sulfite, desiccated.....	¼ ounce
Water.....	1 ounce

(We have taken the liberty of changing the sulfite quantity from the crystalline amount to the modern dry equivalent.)

As we have noted, this is hardly an advisable formula inasmuch as the citric acid offsets any hardening of the emulsion, but the formula should be a boon for workers with print-control processes who have to deal with the problem of factory pre-hardening of emulsions.

Turning to the formulas issued by the Eastman Kodak Company, we find several which are of interest.

Kodak SB-1a—Stop Bath

Acetic acid, 28%.....	4 fl. oz.
Water to make.....	32 ounces

This is a special bath for materials used in the graphic arts. These materials are usually developed in a very short time, and the interval of time between immersion and complete neutralization, while insignificant in an ordinary negative, would be ample for sufficient continued development to produce uneven image formation. Therefore the stronger solution, which provides what is practically an instantaneous stop to the development.

The use of sodium sulfate as an anti-swelling agent has been discussed, but as this agent only acts while the film is actually in contact with the solution, and as alum hardening takes an appreciable period of time, the gelatin might swell in the period after removal from the sulfate and before tanning. Therefore for high temperature processing we may use:

Kodak SB-4—Hardening Bath

Potassium chrome alum.....	1 ounce
Sodium sulfate, desiccated.....	2 ounces
Water to make.....	32 ounces

($4\frac{1}{2}$ ounces of crystalline sulfate may be substituted.) Agitate 45 seconds after immersion. Harden for at least 3 minutes. Rinse between developer and hardener if temperature is below 85° F.

Here we have the **suppressing** effect of the sulfate continued until the actual hardening has fixed the emulsion in place. You might compare the two actions to one man holding a door shut in the face of a storm by pushing against it with both hands. If he moves away the wind will blow the door open. However, if he holds it until someone else can come and nail it shut, then he can leave and the door will remain closed. It is always possible, of course, for a third person to come and withdraw the nails (soak negative in citric acid) and permit it to blow open again.

There is another stop bath which may well be used when the negatives are to remain in the short-stop for more than a few minutes. This is not a hardening stop, but simply an anti-swelling bath:

Kodak SB-5—Stop Bath

Water.....	16 ounces
Acetic acid, 28%.....	1 ounce
Sodium sulfate, desiccated.....	1½ ounces
Water to make.....	32 ounces

Discard after 25 rolls have been stopped

Then we have a hardener that is used for films which are to be given some chemical treatment which has a decided swelling action, and many of them swell emulsions to a dangerous degree.

Kodak SH-1—Special Hardener

Water.....	16 ounces
Formalin.....	2½ drams
Sodium carbonate, desiccated.....	73 grains
Water to make.....	32 ounces

Harden in the above for 3 minutes, then immerse for 5 minutes in a fresh acid fixing bath, and wash thoroughly before giving any further chemical treatment.

In the Kodak F-5 fixing bath we have boric acid added for reasons which we have already discussed, and also the Kodak F-6 which is similar but odorless:

Kodak Fixing Baths—	F-5	F-6
Warm water.....	20 oz.	20 oz.
Hypo.....	8 oz.	8 oz.
Sodium sulfite, desiccated.....	½ oz.	½ oz.
Acetic acid, 28%.....	1½ oz.	1½ oz.
Boric acid crystals.....	¼ oz.
Kodalk.....	½ oz.
Potassium alum.....	½ oz.	½ oz.
Water to make.....	34 oz.	32 oz.

If F-6 is used after a stop bath such as a plain acid rinse, it will have a life about equal to F-5, but if this rinse is omitted the life of F-6 is about half that of F-5.

So far we have considered the usual run of processing, but it must have occurred to you that in all our discussion of neutralization and life of the fixing bath we have considered only the average negative. What of the high-contrast negatives developed in a caustic developer? Surely such a developer will knock out the hypo acidity in short order. For such highly alkaline developers we have a special fixing bath, Kodak F-10:

Kodak F-10—Fixing Bath

Warm water.....	16 ounces
Hypo.....	11 ounces
Sodium sulfite, desiccated.....	¼ ounce
Kodalk.....	1 ounce
Acetic acid, 28%.....	2¼ ounces
Potassium alum.....	¾ ounce
Water to make.....	32 ounces

Wash thoroughly and WIPE EACH NEGATIVE CAREFULLY before drying.

There are times when it is necessary to avoid any hardening. This is true when the negative is to be swelled for special process work and in other cases. For such negatives we have:

Kodak F-24—Fixing Bath

Warm water.....	16 ounces
Hypo.....	8 ounces
Sodium sulfite, desiccated.....	145 grains
Sodium bisulfite.....	365 grains
Water to make.....	32 ounces

This fixer should not be used at a temperature above 65° F. When it is used, and particularly when the negative is given a subsequent bath in a five per cent solution of citric acid, the emulsion may swell to the extreme limit; in fact, care must be taken that it does not advance to the point where the gelatin begins to dissolve.

Fixing is a much more fascinating subject than the dreary old hypo bath would lead us to think. There are special methods, and it gives us a chance to exercise our judgment and skill. But there are two other steps which, while apparently the epitome of mechanical monotony, also have unexpected effects upon the emulsion, and in which the exercise of intelligent control may mean the difference between a good and a very poor negative. These are the steps of washing and drying, which will next occupy our attention.

Washing.

The purpose of washing is to remove the thiosulfates from the emulsion, both the soluble silver sodium thiosulfate and the "hypo" itself which has penetrated. This is a simple step and an obvious one. While laboratory experiments demonstrated that five changes of water separated by two-minute intervals will bring the hypo content of a negative far below the danger-point, and while most amateur negatives are washed in running water for a half-hour or more, still one of the most important factors in the loss of negatives is insufficient washing!

The difficulty lies in the fact that we are not "washing" the film at all! Washing is in a sense a chemical reaction, and has very little in common with the soap-and-cloth scrubbing usually associated with the term. The gelatin coating on the film has, as we have learned, a cellular structure, and the only way those cells can be filled or emptied is by means of molecular

seepage through the wall membranes. This process of osmosis is definitely affected by the character of the solution and by its specific gravity.

After fixing we have a gelatin whose cells are filled with (a) metallic silver, (b) silver sodium thiosulfate, and (c) sodium thiosulfate. The silver (a) makes up the image, but the thiosulfates (b) and (c) must be removed. If this gelatin (film) is placed in cold water, the thiosulfate solution will seep outward into the water, and the water will seep into the cells. Allowed to go on to completion, this interchange will continue until the hypo concentration is the same in the cells and in the water which lies next to the film. This condition, when reached, is known as **equilibrium**.

However, there is one tricky factor which must be taken into consideration. Suppose you have a film which has just been removed from hypo. Assume that this film carries with it 5 cc of 25 per cent hypo. It is placed in a tray and 95 cc of water added. This brings the total liquid volume up to 100 cc. If equilibrium is reached, the hypo which was in 5 cc should be distributed throughout the entire volume, and as 5 cc of 25 per cent solution represents 1.25 grams of pure hypo, this would mean that the solution is reduced to a 1.25 per cent solution at the first immersion. However, if the film is placed in the water and allowed to remain there without attention, what you will actually have is an equilibrium at about 10 per cent concentration with the water at the top of the tray showing no measurable trace of hypo at all!

Hypo solution is heavier than water and sinks to the bottom of any water solution. Therefore, the water immediately above the film would react, but the hypo solution would not diffuse throughout the water unless it was allowed to remain a very long time, and then there would not be an equilibrium established throughout the water.

If two films are placed in the solution, the equilibrium in the case of the bottom one would be established at perhaps 15 to 18 per cent, as the upper film would prevent any rapid diffusion between the films. Now ordinarily the first washing reduces the concentration to 1.25 per cent, the second to 0.0625 per cent, the third to 0.003125, the fourth to 0.00015625, and the fifth to 0.0000078125 per cent. As we have found that the presence of 0.01 per cent hypo (one part in ten thousand) in the negative is not injurious, the third washing in the above scale would have reduced the concentration to one-third of this permissible minimum and would be, in a manner, trebly safe.

But if we had two films together, and carried the two through the same treatment, separating them at each change of water, the result would be entirely different. We shall assume that the reduction is such that the successive equilibria are reached at 20.0 per cent instead of at 5 per cent. Then the first washing will reduce the 25 per cent to 5 per cent, the second to 1 per cent, the third to 0.2 per cent, the fourth to 0.04 per cent, and the fifth to 0.008 per cent.

When this type of washing is done, the end of the fifth water change will find **one thousand times as much hypo** in the lower film as in the upper one, despite the fact that they are separated and placed in the water one at a time! This assumes that the same film is placed underneath every time. If they are alternated the problem becomes complex; but without deviating too far from the truth we can say that alternation simply means duplication of each step, so that instead of three changes we should require six, and so on. This is not strictly true, because of the slight diffusion from the lower film, but it does present a sufficiently accurate picture of the mechanism.

If the films are allowed to remain for two minutes

and then transposed and allowed to lie for another two minutes, equilibrium will be established on a basis of a 10 per cent value, and the changes will then show 1—2.5; 2—0.25; 3—0.025; 4—0.0025; 5—0.00025. Then the concentration is reduced to 1/32 of that of the underneath film in the non-transposed washing; but the concentration is still 0.00025 against 0.000008, or about 32 times as much. In this case seven changes would bring the concentration down to 0.0000025 or less than one-third the concentration of the single film at five changes.

We might carry on these figures until we were lost in the maze, but it would be of slight value. Every film carries over a different quantity of hypo. Every film has hypo of a slightly different concentration. Every washing tray or tank has a different capacity. The whole point is that the film surface must have free access to water and that the water must be agitated to produce equilibrium throughout the entire volume. If these considerations are ignored, a prolonged washing may well fail to free the film from hypo.

Of course, in modern workrooms the films are not washed in successive changes of water, but in a continuous stream of water. This is ideal, provided it is done properly. However, the negatives lost every year through fading prove conclusively that something decidedly wrong is to be found in most amateur washing apparatus.

Get a package of dye powder from your local druggist. The color is immaterial as long as it is strong. Make up a cold-water solution of the dye to a strength which leaves the solution transparent but quite strongly colored. If red, for example, the color should be about that of a red gelatin dessert. Wind an old film in the tank reel and place it in the tank. Now fill the tank with the dye solution

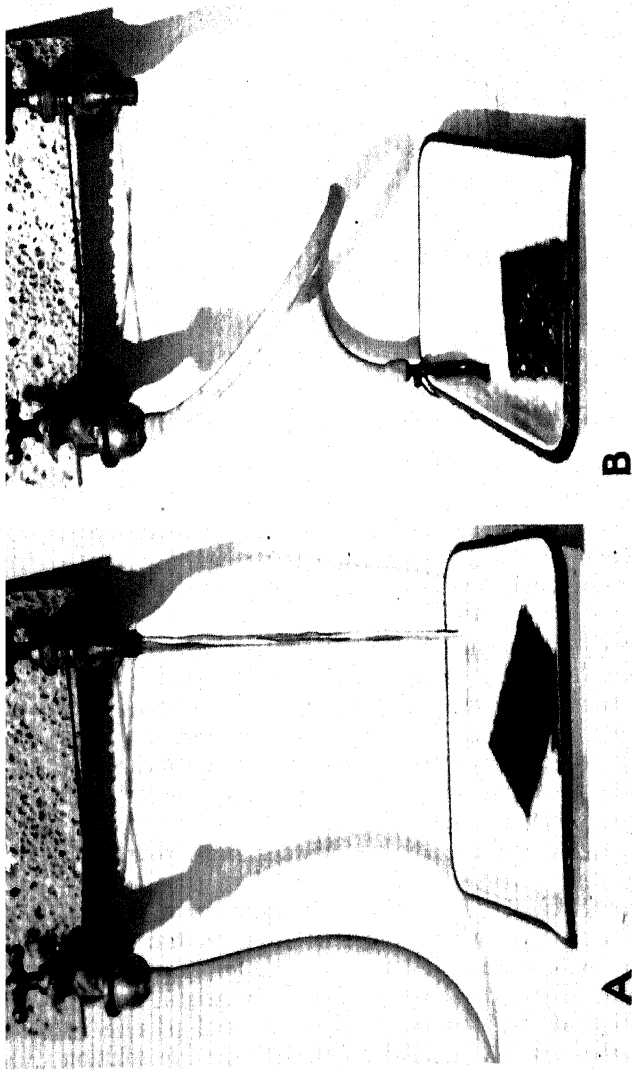


Fig. 67. A, wrong way to wash sheet film. B, spout on hose provides good circulation even if several films are washed together.

and proceed to wash it in your accustomed way. Note the time required to remove the last visible trace of color from the water. This is your base time for washing by that method. If you wash in a tray, do the same thing. When you have determined this time, it will indicate one-fifth the correct washing time. If it takes ten minutes, then your correct washing time is fifty minutes. However, the last traces of color should be removed in an efficient washer in one minute. This does **not** indicate a correct washing time of five minutes, because there is a certain minimum time required for the interchange between emulsion and water, and under the most favorable conditions we may assume this to be ten minutes, which, added to the clearing time of five minutes (all color removed in one minute indicates a clearing time of five minutes) comes to fifteen minutes. This is about the minimum practical washing time.

However, if films have been fixed in a **fresh** hypo bath for at least twice the time required for clearing in the hypo, and if the washing is done with a forceful stream of water which will clear the test color in less than a half minute, you may feel comparatively safe with a ten-minute wash. But remember this is not seven, or eight, or even nine minutes, but a full **ten minutes**, which may be carried to eleven or twelve for safety. In short, the ten-minute period should be regarded as the irreducible minimum.

Tank Washing.

If you wash simply by letting a stream of water run into the tank or tray, you should make a practice of washing for at least forty-five minutes. This is about the least efficient method we have, for the fresh water simply skids off the hypo solution at the bottom of the tray or tank and then out again.

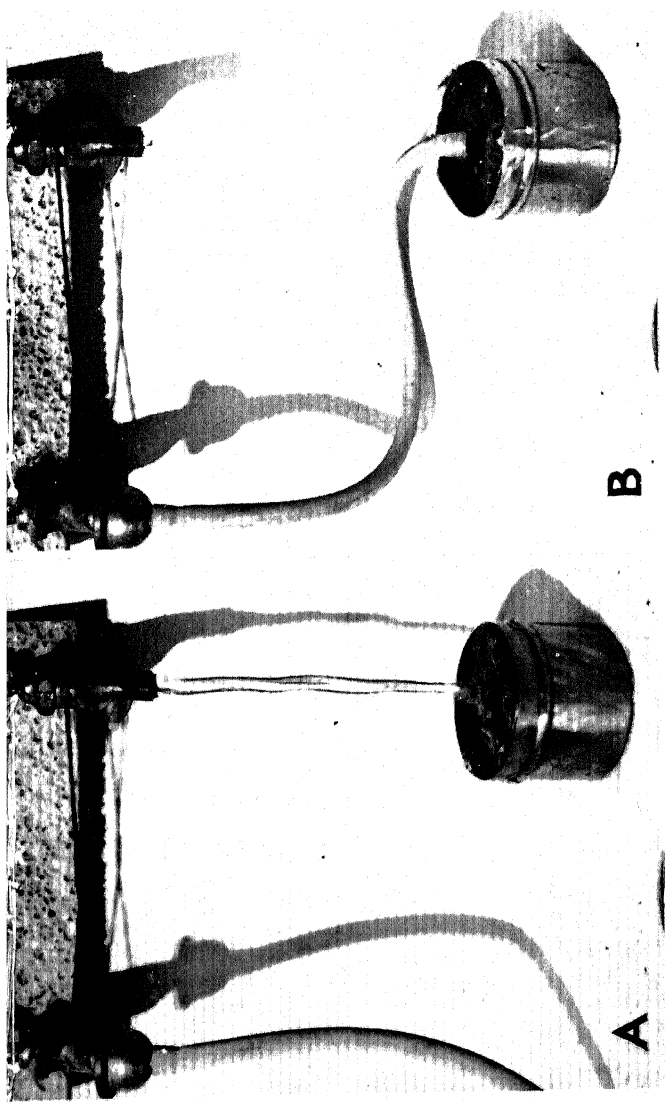


Fig. 68. A, inefficient washing in a rollfilm tank. B, hose flushes the tank thoroughly and discharges hypo-laden water.

For tank washing it is advisable to have a rubber hose attached to the faucet. The other end of this hose is fitted with a glass or metal nozzle, which is brought to a comparatively small opening so that a slow initial stream of water will have considerable force. The best thing to use is a piece of $\frac{1}{4}$ -inch copper tube which is flattened at the end to provide a wide, thin stream. The tube is bent at a right angle to the direction of the hose, and if you want to be real fancy, solder the tube to a heavy film clip which is wide enough to pass over the edge of the tray. This will enable you to fasten the tube to the tray (or tank) with the nozzle projecting in any desired angle. For rollfilm tanks the nozzle is left straight and is inserted into the central core of the reel (see Figs. 67, 68).

For safety the tube may be coated inside and out with celluloid cement which will prevent any possible reaction, but as copper is inert in the presence of pure water the precaution is almost excessive. The same stream which would be a quiet trickle from an open faucet will now have sufficient force to set up a rapid circular current in a tray or cause a slight "boiling" at the top of a tank, both actions effectually clearing any solution from the bottom of the tray or tank.

Another device which is useful is the Eastman tray siphon, which acts to provide efficient hypo removal. There is another device (BeeBee) consisting of a number of cloth "pages" between which the negatives may be placed and then water allowed to run down these cloth sheets. This device is intended primarily for prints and is not long enough for uncut rolls, but for sheet and pack films it is efficient.

For washing single rolls there is a combination water nozzle and film clamp which supplies water at the top of the film and permits it to run down. In fact, there are many devices available for washing, including regular washing tanks. If (a) a forceful

stream is used, (b) if the stream is directed toward the bottom of the container, (c) if the stream sets up a more or less circular current, and (d) if the film has free access to the water throughout its area, then washing may be considered satisfactory.

We have already discussed the substitutes for washing, namely the hypo eliminators. The permanganate method is good enough to hasten elimination in tropical countries when a second washing is to be used, but there is nothing but water which is entirely safe for permanent washing! Any hypo eliminator will only convert the thiosulfates remaining in the film to some other substance, and as this conversion must leave some if not all the sulfur in the gelatin, the permanence of the film is open to serious question. Most experimenters are agreed that the only safe substitute for washing in water is washing in plenty of water.

Drying.

After the film is washed, it must be dried in such a manner that the image shall in no way be disturbed. This is a serious problem, and many amateurs who carry through to this step lose their films in the final stage of drying. Film drying is something more than ordinary drying, for we again have the seepage. This time there is no interchange, but there is an attempt to reach a balance between the concentration of water in the film and the moisture content of the air in which the film is dried. If the humidity is above ninety, the drying will be tremendously prolonged, and the surface of the film will remain very moist. Drying will be a matter of the setting of the gelatin. The gelatin will dry from the edges inward, and if the humidity changes and the process becomes hastened there will be a difference in density. Therefore,

just as it is essential to provide a constant supply of clean water to the film surface in washing, in drying it is essential to keep a constantly renewed supply of dry air so that the constant unbalance will promote the removal of water from the film.

When a film is removed from the water, the first thing to do is to scrub it. This must not be taken too literally; but simple wiping is rarely enough. There may be substances in the hypo and in the water which are deposited upon the film surface, and becoming "set" in the tacky gelatin tend to adhere. A well-hardened film is less likely to be so affected than a soft one. However, each film is subjected to a gentle but firm rubbing with clean, wet cotton. After the scrubbing on both sides, the film is wiped down. There are various methods of doing this.

Some persons leave fingerprints on everything they touch, evidence that their skin is active in secreting oil. Others may handle sensitive materials freely and never leave a print. Those whose fingers are free from natural oil will find it satisfactory to wet the hands thoroughly and strip the film between the first and second fingers. This, repeated two or three times, flushes off the surplus water and tends to remove any surface residue (see Figs. 69, 70). Others can wet cotton and squeeze it out as dry as possible. The film is wiped with this, and the absorbent quality of the cotton takes up the moisture from the film surface. Be very careful about leaving cotton fibers on the film surface. Single fibers, if short, are very difficult to see, yet they make tremendous "wrigglers" on the negative which is subjected to enlargement.

Drying with Sponges.

Another device is the rubber sponge, which is all right if one of extremely fine grain is used; but it has

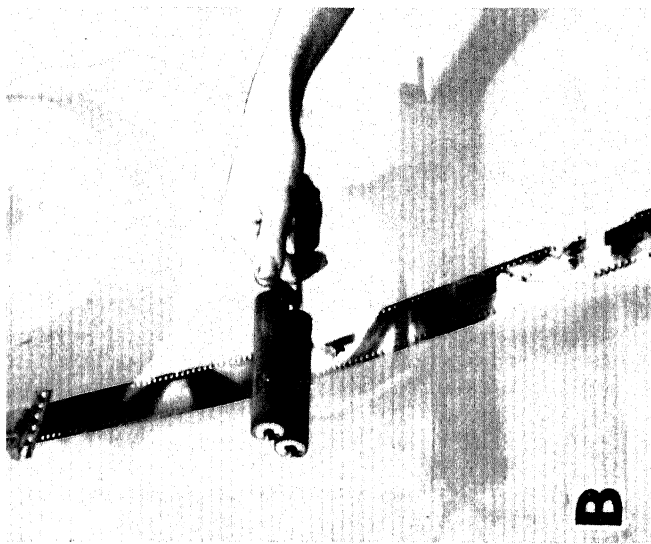
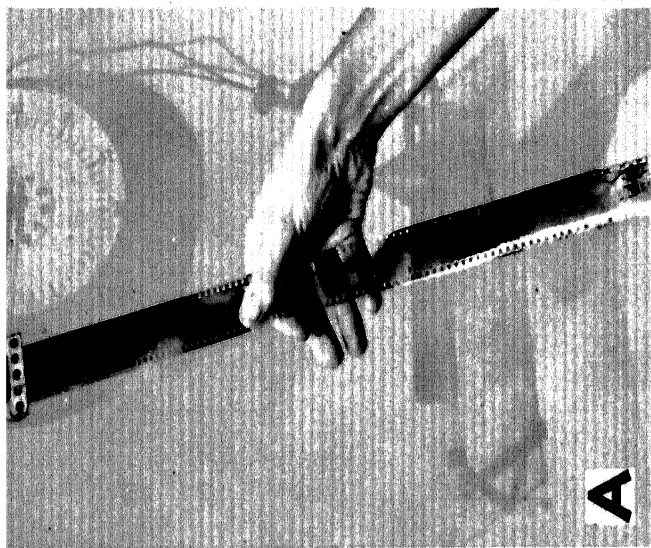


Fig. 69. A, excess water can be stripped from the film with the fingers. B, a roller squeegee serves the purpose equally well.

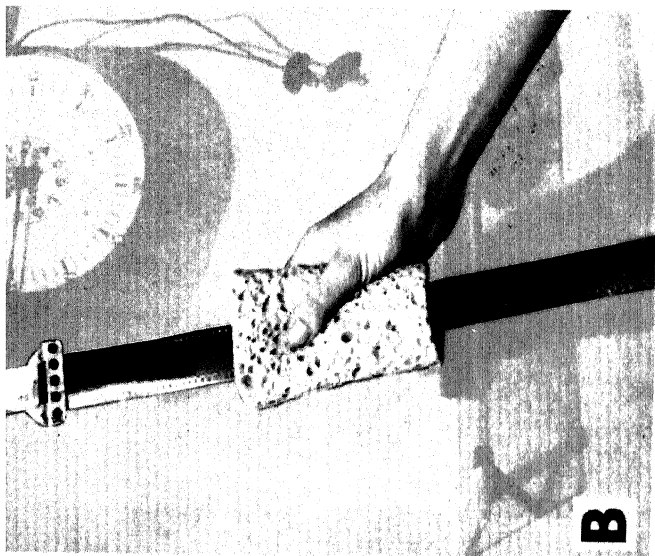
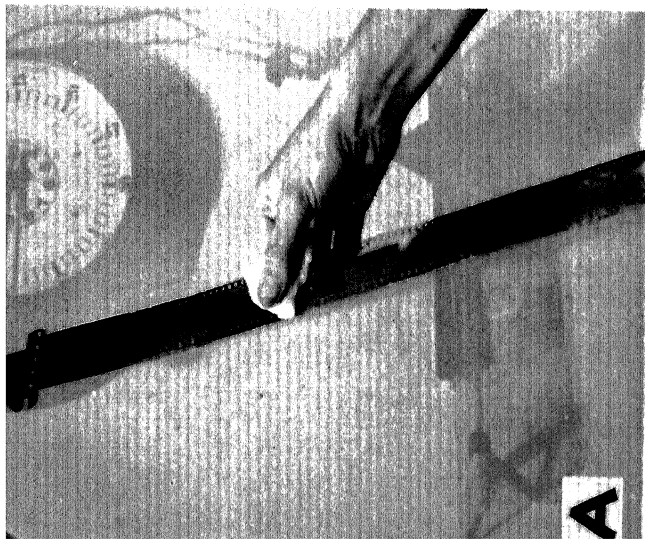


Fig. 70. A, sediment, scum, and excess water is wiped from film with wet cotton swab. B, a viscose sponge used for same purpose.

a low power of absorption and requires several applications to remove the surface water, each application endangering the film. Rubber sponges must be tested thoroughly, for many have tiny hard projections which will scratch a wet emulsion even if it has been hardened.

A chamois skin kept in a jar of water (with a crystal or so of thymol or menthol to prevent bacterial action and "souring" of the water) is good. It is soft, absorbent, and rarely leaves any deposit.

Then there are the special wipers. Some of these are simple rubber rollers held together by spring tension—for all the world like a miniature clothes wringer open at one end. The film is run between these rollers and the surplus water removed by pressure. Another form of wiper is a pair of tongs with viscose sponges set at the ends; still another is a pair of wooden tongs with small absorbent pads set in the ends.

The viscose sponge, of course, is a standard article in the darkroom, and thousands of them have been used satisfactorily; however, I have found that it is only a matter of time before they start to deposit tiny (practically invisible) grains of their substance upon the film. When the film is dry these get hard, and the film has a slight "sandpapery" feel. Each grain forms a spot which cannot be removed from the film. Therefore, it is essential that these sponges be discarded at the first sign of breakdown.

A suggested standard procedure which will remove more surface water (and so hasten uniform drying) than any method I have tried is this: Wipe down the film, scrubbing lightly at first and then picking up the excess of surface water by stripping through wet fingers (or chamois skin). Then roll film between sheets of Textilex paper with moderate pressure. This leaves only the water which is actually within the

gelatin structure. The film is then given controlled artificial drying. The result is a film of perfect surface and with no water marks, variations in density, or any of the faults which commonly occur in drying.

The use of Textilex paper has been advised repeatedly. Surface drying has always been a serious problem, and the hours spent by amateurs with a roll of blotting paper or a brush, patiently picking off water drops while the film is still wet, indicate the importance of the matter. Blotters have been tried and have always left lint. Mopping with a cloth, sponge, chamois, or other agent has always been only half satisfactory because too much water was left. Therefore, the advent of a blotting paper of great absorbing power, but so hard that it will not leave any lint on the film surface, even a soft surface, is certainly worthy of notice.

Two Systems of Controlled Drying.

Controlled drying may be of two kinds. For roll-films there is the drying machine which depends upon a supply of warm, dry, filtered air to the film. This type of dryer is made commercially by Simmon Brothers. It consists of a heater-blower-filter unit which stands on the floor. Rising from this unit is a pipe of sufficient size to take the strip of rollfilm. The film is lowered into the pipe and the motor started. At first there is a current of cool air which soon begins to warm. This air current is strong enough to prevent any dust from falling into the tube; the air which is forced past the film is thoroughly filtered and dust-free, so that the film is dried in a perfectly conditioned atmosphere.

The heater is set to provide a current of warm, dry air, but not enough heat to approach the melting point even of unhardened gelatin. Thus the film is

dried in a dust-free atmosphere which is kept at a uniform temperature and, within practical limits, at a uniform humidity. Needless to say, the use of the machine saves many films which otherwise would be lost, and prevents the formation of spots and marks of mysterious origin, which ruin negatives.

Another system of controlled drying is not as elaborate, but has many advantages. This is the Craig film dryer. I have not had the opportunity to use this device, but it seems to be well designed. Films upon a skeleton drum (like the old movie film drying drums) rotate above a grating. Beneath this grating a fan blows warm, dry air upward against the film surface. It should be highly satisfactory.

Still another system of controlled drying, one which is based upon the soundest principles and which is easy for the amateur to use, is the infrared drying device. So much that is mysterious has been claimed for infrared that one hesitates to say too much without explanation. It seems absurd to say that this device will dry the emulsion from the inside out instead of from the surface inward. Yet it is simple when you consider the facts.

The heat used in drying a film, when heat is used at all, is from the sun, steam radiator, or like source. Infrared has a marked penetrating power, and when the film is subjected to this heat, there is an action throughout the emulsion to a greater degree than would be the case with most ordinary heat sources. The proof of this lies in the fact that infrared heat is used to dry automobile paint; surface drying of the usual "air-dry" type would cause a hard film to form on the surface, leaving the paint underneath still wet. The result would be slippage and wrinkling of the surface film. Infrared does not necessarily dry the paint from the bottom up, but certainly its action is uniform throughout.

The Wabash Photolamp Corp. makes infrared lamps for drying, and their bulletin on the subject has been of deep interest to many amateurs who have had trouble with drying sheet and pack films. The film is suspended with its edge facing a fan which will carry a current of air across both sides of the film, and facing each side of the film is the infrared lamp (see illustration in Chap. II). The drying time for the average sheet film (previously blotted) is about two minutes, or even less.

Importance of Proper Drying.

It is perfectly clear that hypo removal by washing is a matter of constantly decreasing the concentration. It is also obvious that the remainder at the end of any period must be a fraction of that remaining at the end of the preceding period. This means that even after prolonged washing there must be some infinitesimal portion of hypo remaining in the film. We have assumed that a concentration of 0.01 per cent is safe. Suppose we have reduced the concentration to this amount in a film which has fifty square inches of film surface (a 127 rollfilm, for example). Now, if all the water on that film were to start drying and would concentrate itself into a fairly small drop, the concentration of hypo in that drop would be increased; it would contain far more than enough to produce fading and the other faults due to the presence of hypo.

This is extreme, and water doesn't act just that way; but the gathering of surface drops actually does provide concentration of residual hypo, often to a dangerous degree. In toning and other processes which require freedom from hypo, spots often appear which cannot be accounted for. If it were possible to trace them back, these would usually be found to be areas where drops had formed during drying. So we see

that all this fuss and bother about uniform drying isn't simply myth.

If a film is left in a cool, damp room until the film is dry for a distinct width around the edges and then taken into warm dry air for finishing, the dried film will show a line of density difference between the two stages.

Water drops will often remain long enough to cause movement of the gelatin through surface tension, and the silver under the center of the drop will move toward the edge. When dry, such spots show a dark ring with a much lighter center.

Drops of water on the back of a film will slow up drying on the opposite face of the film and so produce density differences in a film which has been carefully surface dried.

No matter what is done, unless the film has **all** surface moisture removed and the film is then dried in a moving current of warm, dry air, there is a danger of vague spots, many of which are not noticed until the print or enlargement is made, and whose origin is rarely suspected. That is the worst of it all. These spots often are blamed upon the emulsion, upon some mysterious oil whose origin is not located, or upon almost anything other than this most subtle of all sources of error . . . incorrect drying. For a simple step, drying is disproportionately important.

Cleaning and Polishing.

When the film is dry there comes the final step which few amateurs ever consider. This is the cleaning and polishing. It is true that there are some commercial processes available, and one amateur device for after-treatment of films; but the usual amateur considers the dry film ready for filing. No matter what precautions have been taken in washing, scrub-

bing, blotting, and drying, there is almost always a slight residue upon the film. Some of it cannot be removed, so it is important to keep it as low as possible in concentration. On the other hand it is advisable to remove as much as possible.

The dry film is placed upon a pad made up of soft cotton cloth. The face of the film (and both sides in ordinary rollfilm) is lightly but firmly scrubbed with carbon tetrachloride; 35 mm film which has no backing is cleaned on the back with alcohol. Most rubbing alcohols will do nicely. Alcohol softens the celluloid and if used on a pad this solvent action will just be sufficient to clean the surface. Following the alcohol the film may be polished to a mirror finish with a soft cloth.

When the film is cleaned and polished (do not try to polish a film which has a coating on the back, as most films other than 35 mm have) it is ready for the final treatment—the waxing which will protect the surface, make dust removal easy, and tend to keep the film dry but flexible for a long period. Use the “film cleaner and preservative” sold for use on amateur motion-picture films for this purpose. This solution will further clean the film and deposit a wax which will make it possible to polish the surface. This coating will do much toward preserving the films.

Storing.

Finally, file each film in a protective paper or cellophane envelope. **Never roll up films for storage!** The roll will work back and forth under the influence of changing humidity, and even if not handled will in time develop thousands of minute scratches caused by the rubbing of dust particles between the layers. Films should be kept flat (35 mm may be cut into convenient lengths) and each individual film protected

from any other film. Kept this way, your valuable negatives can be preserved in perfect condition for a period of many, many years.

The importance of this last step in negative making cannot be too strongly emphasized. Remember that in most cases it is impossible to make an exact duplicate of a negative by retaking the picture. This is particularly true in portraiture. Pictures taken today will be priceless in years to come. Your negative of a certain person may be the only one in existence at some future date. Photographs of the old homestead, of scenes which will change in the course of time, of special events—these will have historical value as time passes.

Consider every negative as an investment, and treat it accordingly. A well-organized system of storage will pay dividends.

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